

ISSN 2708-7581 (Online)
ISSN-L 2708-7573

JLTM

**Journal
of Learning
Theory and
Methodology**

Scientific journal

April 2026
Volume 7
Number 1



JLTM
LLC OVS

Journal of Learning Theory and Methodology

Abbreviated key-title: J. learn. theory methodol. (Online)

Scientific journal

Three issues per year. Established in 2020

<https://www.ltmjournal.com>. E-mail: editor-in-chief@ltmjournal.com

Edit Editorial Team

Editor-in-Chief

Olha Ivashchenko, Doctor of Pedagogy, Professor Kharkiv State Academy of Physical Culture, Kharkiv, Ukraine

Deputy Editor

Oleg Khudolii, Doctor of Sciences in Physical Education and Sport, Professor Kharkiv State Academy of Physical Culture, Kharkiv, Ukraine

Editorial Areas

Learning Theory and Methodology

- Francesca D'Elia, PhD, Associate Professor — University of Salerno, Italy
- Wojciech J. Cynarski, Prof. Dr hab., Full Professor — University of Rzeszów, Poland

The methodological foundations of learning research are additionally supported by members of the Editorial Leadership with expertise in instructional modeling and experimental design.

Didactics of Motor and Verbal Learning

- Olha Ivashchenko, Doctor of Pedagogy, Professor — Ukraine
- Oleg Khudolii, Doctor of Sciences in Physical Education and Sport, Professor — Ukraine
- Karol Görner, Prof. PaedDr., PhD — Matej Bel University, Slovakia
- Nur Ikhwan Mohamad, PhD, Professor — Sultan Idris Education University, Malaysia

Psychological Foundations of Learning and Skill Development

- Roberto Araya, PhD, Professor — University of Chile, Chile
- Said Lotfi, PhD — Hassan II University of Casablanca, Morocco

Methodology and Measurement in Educational Research

- Francesca D'Elia, PhD, Associate Professor — University of Salerno, Italy
 - Kukuwahyudin Pratama, M.S.Sc. — Institute of Advanced Science, Engineering, and Education (IASEE), Malaysia
-

International Editorial Board

(Members contribute to peer review and provide expert advice within their areas of competence)

- Roberto Araya (Chile)
 - Wojciech J. Cynarski (Poland)
 - Francesca D'Elia (Italy)
 - Karol Görner (Slovakia)
 - Sergii Harkusha (Ukraine)
 - Nur Ikhwan Mohamad (Malaysia)
 - Kukuwahyudin Pratama (Malaysia)
 - Said Lotfi (Morocco)
-

Members of the Editorial Board contribute to the peer-review process by providing subject-specific expertise in accordance with the journal's scope.

Abstracting and Indexing:

Web of Science Research Commons (analytical visibility); CrossRef; ROAD (Directory of Open Access scholarly Resources); DOAJ (Directory of Open Access Journals); ERIH PLUS; ICI Journals Master List / ICI World of Journals; Google Scholar; Open Ukrainian Citation Index (OUCI); Scilit (A database of scientific & scholarly literature); WorldCat

DOI: <https://doi.org/10.17309/jltm.2026.7.1>

Журнал теорії та методології навчання

Abbreviated key-title: J. learn. theory methodol. (Online)

Науковий журнал

Три випуски на рік. Заснований у 2020 році

<https://www.ltmjournal.com>. E-mail: editor-in-chief@ltmjournals.com

Редакційний штат

Головний редактор

Іващенко Ольга, доктор педагогічних наук, професор Харківська державна академія фізичної культури, Харків, Україна

Заступник головного редактора

Худолій Олег, доктор наук з фізичного виховання і спорту, професор Харківська державна академія фізичної культури, Харків, Україна

Редакційні напрями

Теорія навчання та методологія

- Франческа Д'Елія, PhD, доцент — Університет Салерно, Італія
- Войцех Ян Цинарський, Prof. Dr hab., професор — Жешувський університет, Польща

Методологічні засади досліджень додатково забезпечуються членами редакційного керівництва, які мають досвід у моделюванні навчального процесу та експериментальному дизайні.

Дидактика моторного та вербального навчання

- Іващенко Ольга, доктор педагогічних наук, професор — Україна
- Худолій Олег, доктор наук з фізичного виховання і спорту, професор — Україна
- Гернер Карол, Prof. PaedDr., PhD — Університет Матея Бела, Словаччина
- Нур Іхван Мохамад, PhD, професор — Університет освіти султана Ідріса, Малайзія

Психологічні засади навчання та розвитку навичок

- Роберто Арая, PhD, професор — Університет Чилі, Чилі
- Саїд Лотфі, PhD — Університет Хасана II, Марокко

Методологія та вимірювання в освітніх дослідженнях

- Франческа Д'Елія, PhD, доцент — Університет Салерно, Італія
 - Кукух Вахюдін Праама, M.S.Sc. — Інститут передових наук, інженерії та освіти (IASEE), Малайзія
-

Міжнародна редакційна колегія

(Члени колегії беруть участь у рецензуванні та експертному супроводі рукописів відповідно до тематики журналу)

- Роберто Арая (Чилі)
 - Войцех Ян Цинарський (Польща)
 - Франческа Д'Елія (Італія)
 - Карол Гернер (Словаччина)
 - Сергій Гаркуша (Україна)
 - Нур Іхван Мохамад (Малайзія)
 - Кукух Вахюдін Праама (Малайзія)
 - Саїд Лотфі (Марокко)
-

Редакційна колегія забезпечує експертний супровід процесу рецензування та надає фахові консультації відповідно до тематичних напрямів журналу.

Journal of Learning Theory and Methodology
Scientific journal
April 2026, Vol. 7, Num. 1

Contents

Review Article

Olha Ivashchenko, Oleg Khudolii and Mykola Khudolii
Modeling Physical Education as a Learning System: Regional and International Perspectives ... 6-16

Anatolii Lopatiev Pavol Bartik and Mirosława Cieślicka
Epistemological Foundations of Modeling in Motor Action Research: A Narrative Review..... 17-24

Original Scientific Article

Nevitaningrum, Pepep Mochamad Syafei, Gumilar Mulya, Trisnar Adi Prabowo,
Oktaviarini Yahya Rahmadhanty and Putu Deanita I Desta Suryani
**Healthy Lifestyle Program to Improve Physical Literacy and Physical Fitness of Junior
High School Students: A Quasi-Experimental Approach** 25-36

Vicente E. Montano and Archie G. Reyes
**Beyond Course Averages: A Generalized Bayesian Hierarchical Framework for Course-Level
Learning Evaluation** 37-48

Oksana Blavt, Gennadii Iedynak and Yan Bezhrebelnyy
**Gamified Inclusive Physical Education as an Adaptive Rehabilitation Model for University
Students with Blast Traumatic Brain Injury.....** 49-55

Журнал теорії та методології навчання
Науковий журнал
Квітень 2026, Том 7, Номер 1

Зміст

Оглядові статті

Ольга Іващенко, Олег Худолій, Микола Худолій

Моделювання фізичного виховання як навчальної системи: регіональний та міжнародний виміри..... 6-16

Анатолій Лопатєв, Павол Бартік, Мирослава Цислицька

Епістемологічні засади моделювання у дослідженні рухових дій: наративний огляд..... 17-24

Оригінальні наукові статті

Невітанінґрум, Пепеп Мохамад Сяфеї, Гумілар Муля, Тріснар Аді Прабово, Октавіаріні Ях'я Рахмадханті, Путу Деаніті Ай Деста Сур'яні

Програма здорового способу життя для підвищення фізичної грамотності та фізичної підготовленості учнів молодшого підліткового віку: квазіекспериментальне дослідження 25-36

Вінсенте Е. Монтано, Арчі Г. Рейєс

Поза межами курсових середніх: узагальнена байєсівська ієрархічна методологічна рамка оцінювання результатів навчання на рівні курсів..... 37-48

Оксана Блавт, Геннадій Єдинак, Ян Безгребельний

Гейміфіковане інклюзивне фізичне виховання як адаптивна реабілітаційна модель для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою..... 49-55



Modeling Physical Education as a Learning System: Regional and International Perspectives

Olha Ivashchenko^{1ABCD}, Oleg Khudolii^{1ABCD} and Mykola Khudolii^{1ABCD}

¹Kharkiv State Academy of Physical Culture

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.1.01

Abstract

Background. Contemporary learning research increasingly conceptualizes educational processes as controllable, adaptive, and feedback-driven systems. Despite this shift, physical education is often treated as conceptually separate from general learning theory and predominantly interpreted as an applied or norm-oriented activity. Such a reduction limits opportunities for systemic analysis, instructional design, and the integration of formative assessment mechanisms.

Objectives. The purpose of this article is to reconceptualize physical education as a learning system from the perspective of learning theory and to analyze regional and international approaches to modeling learning processes and pedagogical regulation of learning outcomes.

Materials and Methods. The study was conducted as a narrative review. Its methodological basis is a conceptual analysis of monographic works and publications in peer-reviewed journals addressing learning process modeling, pedagogical control, adaptive learning, and instructional design in physical education. Source selection followed a conceptually oriented strategy aimed at identifying theoretically and empirically grounded models of learning systems.

Results. The analysis demonstrates that physical education can be interpreted as a structured learning system comprising learning goals, operationalized outcomes, feedback mechanisms, and regulatory pedagogical decisions. Learning outcomes are conceptualized as dynamic states of learning that change in response to instructional organization. Regional models illustrate how pedagogical control and the classification of learning states can be used to adapt instructional influences under conditions of learner heterogeneity.

Conclusions. Physical education can be regarded as a legitimate domain of learning theory capable of providing conceptually coherent and empirically grounded examples of controllable and adaptive learning systems. Integrating motor learning within the learning sciences expands opportunities for interdisciplinary analysis of learning processes and contributes to bridging cognitive, procedural, and physical domains of learning.

Keywords: physical education, learning system, learning theory, modeling, pedagogical control, adaptive learning, instructional design.

Introduction

In contemporary research on learning, there is a growing tendency to expand the understanding of what constitutes a learning process. Learning is no longer limited to the transmission of declarative knowledge or the development of purely cognitive skills but increasingly encompasses complex systems of action, regulation, feedback, and adaptation (Bransford et al., 2000; Sawyer, 2014). In this context, physical education emerges as a legitimate object of learning theory, as it involves the purposeful formation of motor actions, the development of functional capacities, and the management of learning outcomes under conditions of limited resources and

heterogeneous individual learner characteristics (Schmidt & Lee, 2019).

Despite this, in many educational systems physical education remains conceptually separated from general learning theory. It is often treated either as an auxiliary activity aimed at health promotion or as an applied domain of sports training that does not require sophisticated learning models (Bailey, 2006; Kirk, 2010). Such an approach constrains opportunities for systematic analysis and instructional regulation, reducing pedagogical decision-making to empirical or intuitive practices.

This problem becomes particularly acute in the context of declining levels of motor competence and physical activity among children and adolescents, a trend documented across countries regardless of socio-economic context (World Health

Organization, 2020; van Sluijs et al., 2021). International research points to fragmented approaches to organizing physical education, insufficient integration of assessment into the learning process, and weak alignment between instructional goals and actual learning outcomes (OECD, 2019). At the same time, regional educational systems, particularly in Central and Eastern Europe, face additional challenges related to limited resources, normative inertia, and a lack of tools for pedagogical control and instructional regulation.

Within this context, the concept of modeling the learning process acquires particular significance. In learning theory, modeling is viewed as a means of formalizing complex educational systems, identifying key variables, and establishing relationships between instructional inputs and learning outcomes (Biggs, 1996; Reigeluth, 2013). Models make it possible to move beyond descriptive analysis toward prediction and evidence-informed pedagogical decision-making. Applying this approach to physical education opens the possibility of reconceptualizing it as a controllable learning system rather than a collection of isolated exercises or standardized norms.

Regional scientific traditions in physical education, particularly those developed within the Ukrainian pedagogical context, have accumulated substantial empirical and theoretical material related to the modeling of learning processes, pedagogical control, and the diagnosis of motor preparedness. These studies were typically oriented toward practical objectives of school education, such as optimizing instructional loads, individualizing learning, and improving the effectiveness of motor skill acquisition. However, their potential contribution to the development of general learning theory has often remained insufficiently articulated in the international context (Sfard, 1998; Greeno, 1998).

At the same time, international scholarly discourse increasingly employs concepts such as learning systems, adaptive learning, formative assessment, and evidence-based instructional design (Black & Wiliam, 1998; Hattie & Timperley, 2007). Within this body of research, physical and motor learning are recognized as important components of the broader learning sciences, yet often without reference to the pedagogically grounded models developed within regional educational traditions (Sawyer, 2014). This situation creates a gap between local empirical developments and global theoretical frameworks.

Against this background, there is a clear need to integrate regional experience in modeling physical education into the broader context of learning theory. Such a reconceptualization not only enhances the theoretical visibility of regional research but also enriches international discourse with concrete examples of controllable learning systems oriented toward the development of motor actions and functional capacities of learners.

The aim of this narrative review is to provide a conceptual analysis of approaches to modeling physical education as a learning system from the perspective of learning theory and to interpret regional and international perspectives on their application. The article synthesizes theoretical positions and empirical generalizations that support viewing physical education as an integrated learning system with clearly defined goals, feedback mechanisms, and instructional control strategies (Illeris, 2018; Merrill, 2002).

Materials and Methods

Methodological Positioning of the Narrative Review

This article is conducted in the format of a narrative review. The choice of this methodological approach is determined by the nature of the research task, which is not focused on synthesizing the results of individual experimental studies but on the conceptual reconceptualization of physical education as a learning system from the perspective of learning theory (Baumeister & Leary, 1997; Grant & Booth, 2009).

Unlike systematic or meta-analytic reviews, a narrative review allows for the integration of heterogeneous sources of knowledge—including theoretical frameworks, methodological approaches, and generalized empirical findings—into a coherent conceptual framework. This format is particularly appropriate when the aim is to identify conceptual linkages, explain the evolution of ideas, or interpret evidence within a broader interdisciplinary context of the learning sciences (Green et al., 2006; Grant & Booth, 2009).

The methodological foundation of the review is based on the analysis of monographic works addressing the modeling of physical education processes, pedagogical control, and the management of learning outcomes in school education. These sources are treated not as isolated empirical reports but as a coherent conceptual system integrating theory, research methods, and pedagogical practice. Particular attention is given to the logic of model construction, approaches to interpreting results, and their alignment with key principles of learning theory (Sawyer, 2014).

Within the review, the following analytical strategies are employed:

- **conceptual analysis**, aimed at identifying core concepts and assumptions underlying the modeling of physical education;
- **interpretative synthesis**, enabling the integration of regional research traditions with international theoretical approaches;
- **pedagogical interpretation**, focused on examining physical education as a learning process through the lenses of learning theory, instructional design, and educational measurement (Illeris, 2018; Merrill, 2002).

The narrative character of the review implies a selective approach to sources, prioritizing conceptual relevance over formal inclusion criteria typical of systematic reviews. This approach is methodologically justified when the objective is to construct a generalized theoretical perspective rather than to evaluate the effectiveness of specific interventions (Baumeister & Leary, 1997; Green et al., 2006).

A key methodological assumption of the review is the treatment of motor learning as part of a broader educational process. Accordingly, the analysis employs concepts central to learning theory, including learning goals, feedback, adaptation, control, learning outcomes, and instructional regulation. This perspective avoids reducing physical education to biomedical or purely sport-oriented models and ensures its integration into the interdisciplinary domain of the learning sciences (Sfard, 1998; Greeno, 1998).

Thus, the methodological position of this narrative review lies in combining regional monographic expertise with international theoretical frameworks of learning theory.

Table 1. Conceptual Mapping of Source Types Included in the Narrative Review

Source category	Focus	Role in the review
Learning theory frameworks	Learning systems, feedback, regulation	Conceptual anchoring
Instructional design models	Goal alignment, task sequencing	Structural modeling
Motor learning research	Skill acquisition, retention, transfer	Domain-specific learning logic
Pedagogical control studies	Measurement, adaptation, differentiation	Feedback and regulation mechanisms
Regional monographs and studies	Modeling and control in PE	Empirical grounding and contextualization

This approach provides a foundation for the subsequent analysis of physical education as a learning system and for discussing its conceptual contribution to contemporary learning research.

Data Source and Search Strategy

This narrative review is based on an integrative analysis of monographic works, articles published in peer-reviewed journals, and international conceptual documents addressing physical education, motor learning, and learning systems. Primary attention was given to sources in which physical education is explicitly or implicitly interpreted as a structured, controllable, and feedback-driven learning process.

Source selection was conducted through targeted searches in scientific databases and publisher platforms (Scopus, Google Scholar, Crossref, journal websites), as well as through backward citation tracking of key theoretical works. The review primarily focused on sources published between 1995 and 2025, reflecting the development of contemporary learning theory and instructional design. The selection process was conceptually oriented, consistent with the aims of a narrative review rather than exhaustive literature coverage.

Sources were included if they contained at least one of the following conceptual components:

- modeling of learning or instructional processes;
- pedagogical control and feedback mechanisms;
- adaptive or differentiated learning in physical education;
- operationalization of learning outcomes in the motor domain.

Sources were included if they provided either (a) theoretically grounded models of learning systems, or (b) empirically validated approaches to pedagogical control and adaptation relevant to physical education. Priority was given to works that explicitly connected instructional design, feedback, and learning outcomes.

Regional sources were included when they presented clearly articulated models, pedagogical decision-making logic, or instrumental approaches relevant to learning theory. International sources were used to conceptually anchor the analysis within the learning sciences and instructional design. This strategy enabled a theoretically grounded synthesis of regional and international perspectives on physical education as a learning system.

The table 1 illustrates the conceptual logic of source selection rather than an exhaustive list of included publications, consistent with the aims of a narrative review.

The present review deliberately refrains from proposing a new schematic framework or visual model of physical education as a learning system. Although diagrammatic

representations are common in educational research, their proliferation has not necessarily led to greater conceptual clarity or cumulative theoretical progress. In the context of this narrative review, the primary analytical contribution lies not in introducing another formalized scheme, but in reinterpreting physical education through the conceptual language of learning theory—specifically, by treating learning outcomes as dynamic learning states shaped by feedback, regulation, and instructional decision-making.

Results

Physical Education as a Learning System: Conceptual Foundations

Viewing physical education as a learning system is grounded in the understanding of learning as a controlled, goal-oriented, and feedback-dependent process. Within this framework, physical education ceases to be a collection of isolated exercises or normative requirements and is instead conceptualized as a structured educational process in which outcomes are determined not only by the volume of physical activity but also by the quality of instructional design, regulatory mechanisms, and the adequacy of feedback (Bransford et al., 2000; Sawyer, 2014).

Learning Goals and Outcomes in Physical Education

From the perspective of learning theory, any learning system presupposes clearly defined goals and operationalized outcomes. In physical education, such outcomes include acquired motor skills, levels of motor abilities, functional readiness, and students' capacity for further learning and physical activity. Importantly, these outcomes have a learning character: they are formed gradually, depend on prior experience, and are subject to pedagogical influence (Illeris, 2018; Schmidt & Lee, 2019).

In contrast to approaches that emphasize final indicators or normative achievements, a learning-oriented perspective conceptualizes physical education outcomes as dynamic learning states that change in response to the organization of the instructional process. This creates opportunities to adapt learning goals and instructional means to individual learner characteristics (Biggs, 1996).

Structure of the Physical Education Learning System

Within a systems approach, physical education can be described as a learning system comprising interrelated components: learning content, learning conditions, learners, feedback mechanisms, and regulatory decisions. This structure is fundamentally similar to learning models used

Table 2. Key Constructs of the Physical Education Learning System and Their Operationalization

Construct	Conceptual Definition	Observable Indicators	Measurement Tools	Pedagogical Decisions
Learning goals	Planned learning outcomes	Level of motor skill acquisition	Tests, learning tasks	Task selection and progression
Learning tasks	Structured motor actions and exercises	Accuracy, coordination, stability	Observation, checklists	Modification and sequencing
Learning conditions	Organizational and load parameters	Intensity, volume, frequency	Load logs	Adjustment of regimes
Feedback	Information about learning progress	Error dynamics, progress	Formative assessment	Immediate/delayed correction
Regulatory decisions	Adaptation of the learning process	Task difficulty changes	Threshold rules	Instructional differentiation
Learning outcomes	Dynamic learning states	Retention, transfer	Repeated measurements	Revision of goals

in other educational domains and ensures the conceptual compatibility of physical education with learning theory (Reigeluth, 2013; Merrill, 2002).

Identifying these components makes it possible to conceptualize physical education as a coherent system in which changes in one element inevitably affect the functioning of others. This provides a foundation for systemic analysis and purposeful management of the learning process (Davis & Sumara, 2006).

This structure closely parallels learning models applied in other educational fields and ensures the conceptual alignment of physical education with learning theory (Table 2).

Modeling as a Core Mechanism of the Learning System

Within this system, modeling functions as both a theoretical and practical tool that enables the generalization of instructional experience, identification of regularities, and prediction of pedagogical effects. From a learning theory perspective, a model represents a simplified yet conceptually meaningful reflection of the real learning process that preserves its essential characteristics (Reigeluth, 2013).

In physical education, models make it possible to describe relationships between learning tasks and outcomes, determine optimal instructional load regimes, classify learner states for instructional differentiation, and support data-informed pedagogical decision-making. In this way, modeling serves as a bridge between learning theory and pedagogical practice, facilitating the transition from intuitive decision-making to evidence-based instructional design (Merrill, 2002; Biggs, 1996).

Feedback and Regulation of the Learning Process

One of the defining features of a learning system is the presence of effective feedback. In physical education, this function is implemented through pedagogical control, which allows educators to assess not only achieved outcomes but also the current state of learning. In terms of learning theory, pedagogical control corresponds to mechanisms of formative assessment that support real-time regulation of the instructional process (Black & Wiliam, 1998; Hattie & Timperley, 2007).

Feedback within the physical education learning system informs teachers about the alignment between instructional influences and learners' capabilities, enables the detection of deviations from planned learning trajectories, and creates conditions for individualized instruction. This highlights the fundamental distinction between learning-oriented and norm-oriented models of physical education (Sadler, 1989).

This logic is complemented by the concept of teaching styles in physical education, which conceptualizes the instructional process as a system of pedagogical decisions distributed between the teacher and the learner (Mosston & Ashworth, 2008). This approach reinforces the view of physical education as a controllable learning system, in which adaptivity is achieved through changes in decision structures and feedback mechanisms rather than solely through variation in exercise content.

Adaptivity and Controllability as Learning Principles

Interpreting physical education as a learning system presupposes its adaptivity—the capacity to modify instructional parameters in response to data on learner states and learning outcomes. In this respect, physical education aligns with contemporary models of adaptive learning that are actively explored in the learning sciences (Zimmerman, 2002; Nicol & Macfarlane-Dick, 2006).

Controllability of the learning system is achieved through the integration of modeling, feedback, and regulatory decisions. This enables a shift from standardized, one-size-fits-all programs toward flexible learning trajectories aligned with learners' actual capabilities, consistent with contemporary conceptions of effective instructional design (Merrill, 2002; Reigeluth, 2013).

Regional Perspective: Modeling and Pedagogical Control in Ukrainian Physical Education

The regional dimension of modeling in physical education has developed in response to specific educational and social challenges faced by the school system. In the Ukrainian context, these challenges are associated with the combination of high demands for learning outcomes, limited resources, and the need to work with student groups that are highly heterogeneous in terms of preparedness. These conditions have driven the development of approaches in

which physical education is viewed as a controllable learning system rather than as a set of standardized norms (Khudolii, 2019; Ivashchenko, 2016, 2020).

Educational Context and the Demand for Learning Controllability

For a long time, the Ukrainian system of physical education operated within a norm-oriented paradigm, focusing primarily on the fulfillment of curriculum requirements and attainment of prescribed performance indicators. However, empirical observations and results of pedagogical research have demonstrated the limited effectiveness of this approach under conditions of pronounced differentiation among students in health status, motor preparedness, and learning motivation. This has created a demand for tools capable of ensuring controllability and adaptability of the learning process, particularly through modeling instructional influences and systematic pedagogical control (Ivashchenko, Nosko et al., 2019; Iermakov et al., 2021; Mugurdinova & Iermakov, 2022).

Pedagogical Control as a System-Forming Element

Within the regional research tradition, pedagogical control is regarded as a key component of the learning system in physical education. Its function extends beyond outcome evaluation to include diagnosis of the current learning state, enabling evidence-informed pedagogical decisions. Control is integrated into the learning process and serves as a continuous feedback mechanism linking instructional influences with learning outcomes, thereby supporting the adjustment of instructional regimes and workloads (Ivashchenko et al., 2019; Ivashchenko et al., 2020; Iermakov et al., 2021).

This approach conceptually aligns physical education with principles of learning theory, in which formative assessment constitutes the foundation of adaptive learning. In practical terms, this implies a shift from episodic testing to systematic monitoring of students' motor and functional preparedness, allowing the dynamics of learning effects to be tracked over time (Ivashchenko, 2020; Khudolii, Kapkan et al., 2020).

Modeling the Learning Process in School Physical Education

In regional studies, modeling is used as a tool for describing, analyzing, and optimizing the learning process. Models make it possible to generalize the results of pedagogical experiments and translate them into decision-making rules that are understandable for practitioners. In particular, modeling is applied to determine optimal instructional load

regimes, sequences of motor skill formation, and conditions for the development of motor abilities (Khudolii, 2019; Ivashchenko, 2016; Ivashchenko et al., 2020).

From the perspective of learning theory, such models perform the function of instructional design, as they define the logic of learning organization and ensure alignment between instructional goals and learners' capabilities. Empirical evidence confirms that changes in instructional regimes and exercise structure lead to different immediate and delayed learning effects, which is fundamentally important for controlled learning (Ivashchenko et al., 2020; Khudolii, Iermakov, & Bartik, 2020; Iermakov et al., 2021).

Classification of Learning States and Instructional Differentiation

An important element of the regional approach is the use of classification models to identify states of motor and functional preparedness. From an instructional perspective, these states can be interpreted as levels of learning readiness that are directly relevant for instructional differentiation. The application of pattern recognition and classification methods allows students to be grouped in a theoretically grounded manner and instructional influences to be adapted to their current learning state (Ivashchenko, 2016; Ivashchenko et al., 2019; Iermakov et al., 2021).

Classification makes it possible to identify groups of learners with different instructional needs, adapt tasks and workloads, and prevent overload or insufficient stimulation. This strengthens the learning-oriented nature of physical education and reduces the risk of formal curriculum implementation without genuine acquisition of learning content (Ivashchenko, 2016; Khudolii et al., 2020).

Regional Experience as a Source of Conceptual Generalization

Although regional studies are often oriented toward solving local pedagogical problems, their content has considerable potential for theoretical generalization. Models of physical education developed in the Ukrainian context demonstrate how a learning system can be organized under conditions of limited resources and high variability in learner characteristics while maintaining controllability and predictability of learning outcomes (Ivashchenko, 2016, 2020; Khudolii, 2019).

In this sense, regional experience is not peripheral or secondary, but constitutes valuable material for the development of learning theory, as it illustrates the practical implementation of adaptive learning principles, feedback mechanisms, and instructional differentiation in real educational environments (Khudolii et al., 2020; Khudolii et al., 2025).

Table 3. Conceptual Mapping of Regional Approaches and Learning Theory

Regional Concept	Learning Theory Counterpart	Added Conceptual Value	Pedagogical Implications
Pedagogical control	Formative assessment	Learning regulation	Data-informed decisions
Process modeling	Instructional design	Learning structure	Reduced reliance on intuition
State classification	Levels of learning readiness	Adaptivity	Instructional differentiation
Load regulation	Adaptation parameters	Optimization	Overload prevention
Learning dynamics	Learning trajectories	Long-term control	Progress monitoring

International Perspective: Convergence with Learning Theory and Educational Research

The international scholarly discourse in learning theory and educational research increasingly conceptualizes learning as a systemic, adaptive, and controllable process in which feedback, regulation, and instructional design play a central role (How People Learn; The Cambridge Handbook of the Learning Sciences). Within this context, physical education is gradually being integrated into the broader field of learning sciences, where motor learning is considered alongside cognitive, procedural, and social learning. This integration provides a basis for comparing regional models of physical education with international theoretical frameworks.

Physical Education in International Learning Models

In contemporary international research, physical education is increasingly less likely to be treated as an autonomous discipline isolated from general educational theory. Instead, it is viewed as part of a learning environment in which motor competencies, self-regulation, lifelong learning capacity, and health-related practices are developed (OECD, 2019; United Nations Educational, Scientific and Cultural Organization, 2015). In this sense, physical education converges with other learning domains in which learning goals, feedback, and adaptation of instructional influences play a key role.

International learning-oriented approaches emphasize that learning effectiveness is determined not only by the content of tasks, but also by their organization, sequencing, level of difficulty, and alignment with learners' capabilities (Hattie, 2009; Black & William, 1998). These principles are conceptually consistent with the model-based approach to physical education, in which the learning process is described as a system of interrelated components.

Modeling as a Universal Methodological Language

One of the key points of convergence between regional and international approaches is the use of modeling as a universal methodological tool. In international educational research, models are employed to describe learning processes, analyze interactions between learners and learning environments, and predict learning outcomes (Instructional-Design Theories and Models).

Within this context, models of physical education developed in regional studies can be interpreted as part of a broader tradition of instructional modeling. They meet general requirements of learning theory in that they formalize the structure of the learning process, are grounded in empirical data, and support pedagogical decision-making aimed at optimizing learning outcomes (Complexity and Education).

Feedback and Formative Assessment in an International Context

In international learning theory, feedback is regarded as one of the core mechanisms of effective learning. Formative assessment and adaptation of the learning process are central concepts in contemporary learning sciences (Black & William, 1998; Hattie & Timperley, 2007). From this perspective, pedagogical control as applied in model-based approaches to physical education is conceptually aligned with international understandings of learning feedback.

Adaptive Learning and Motor Competence

International research on adaptive learning highlights the importance of accounting for individual differences among learners in pace, learning style, and outcomes (Zimmerman, 2002). In physical education, these differences are particularly pronounced due to variability in motor competence and functional readiness.

Studies of motor competence demonstrate that the level of motor skill development is closely associated with subsequent learning engagement and physical activity, strengthening the argument in favor of adaptive approaches to organizing physical education (Stodden et al., 2008; Barnett et al., 2016).

International Relevance of Regional Experience

Regional studies of physical education that focus on modeling and pedagogical control demonstrate a high degree of methodological compatibility with international educational research. Their value lies in providing empirically validated examples of learning system implementation in real educational contexts, thereby complementing international theoretical frameworks with concrete pedagogical content.

Conceptual Contribution to Learning Theory

Reconceptualizing physical education as a learning system is of fundamental importance for the development of contemporary learning theory. The materials synthesized in this narrative review demonstrate that physical education not only meets the basic criteria of a learning process but also provides unique opportunities for theoretical analysis of learning as a controlled, adaptive, and measurable system (Khudolii, 2019; Ivashchenko, 2020).

Physical Education as a Full-Fledged Domain of Learning Theory

In traditional educational models, learning theory has primarily focused on cognitive learning, while motor learning has often been treated as peripheral or purely applied. The analysis of model-based approaches to physical education indicates the need to reconsider this assumption. The formation of motor actions, the development of motor abilities, and functional readiness exhibit all key characteristics of learning, including goal-directedness, staged progression, dependence on prior experience, and sensitivity to feedback (Khudolii, 2019; Ivashchenko et al., 2019).

Within this context, physical education emerges as a domain in which learning outcomes are directly observable, measurable, and subject to regulation. This makes it particularly valuable for learning theory, as it enables the investigation of learning processes with a high degree of operationalization of variables and allows for real-time tracking of learning dynamics (Ivashchenko, 2020; Iermakov et al., 2021).

Modeling as a Mechanism for Conceptualizing Learning

One of the key contributions to learning theory discussed in this review is the interpretation of modeling not merely as an analytical tool, but as a mechanism for conceptualizing the learning process itself. In this approach, a model performs

a dual function: it serves simultaneously as a theoretical generalization and as a practical instrument for managing learning (Khudolii, 2019).

Models in physical education make it possible to formalize the structure of the learning process, identify critical parameters of instructional influence, describe relationships between learning conditions and outcomes, and predict learning dynamics. From the perspective of learning theory, this represents a shift from descriptive models toward controlled learning systems in which pedagogical decisions are grounded in theoretically justified and empirically verified relationships (Ivashchenko, 2020; Ivashchenko et al., 2020).

Feedback as a Central Mechanism of Learning

Of particular conceptual significance is the interpretation of pedagogical control as a mechanism of learning feedback. Within the model-based approach, control is integrated into the learning process and used to regulate instructional influences rather than to perform formal evaluation of achievements (Ivashchenko et al., 2019; Iermakov et al., 2021).

In terms of learning theory, this corresponds to contemporary conceptions of formative assessment, in which information about learning outcomes serves as the basis for adapting instructional design. Such an approach makes it possible to maintain an optimal level of task difficulty, avoid both overload and underlearning, and support individualized learning trajectories. In this sense, physical education functions as an example of a learning system with clearly implemented cycles of “action – feedback – adjustment” (Khudolii et al., 2020).

Classification of Learning States and Adaptive Learning

The use of classification models to identify states of motor and functional readiness is directly related to theories of adaptive learning. In an instructional interpretation, such states can be regarded as levels of learning readiness that determine the feasibility and appropriateness of specific instructional interventions (Ivashchenko et al., 2019; Iermakov et al., 2021).

This approach enables the integration of physical education into general models of adaptive learning, in which instructional decisions depend on diagnostic data, learning trajectories remain flexible, and the system responds dynamically to changes in the learner’s state. Consequently, physical education emerges as a natural laboratory for studying adaptive learning systems, which is of significant conceptual value for learning sciences (Khudolii et al., 2020).

Contribution to Interdisciplinary Learning Theory

Reconceptualizing physical education as a learning system contributes to the expansion of learning theory by integrating the motor domain into its conceptual scope. This integration helps reduce the gap between cognitive and procedural learning, connects pedagogical, psychological, and physiological dimensions of learning within a unified framework, and supports the interpretation of learning as a universal process independent of specific subject matter (Khudolii et al., 2020; Khudolii et al., 2025).

This constitutes the key conceptual contribution of the proposed approach: physical education ceases to be viewed as

a “special case” and acquires the status of a full-fledged object of learning theory, capable of enriching general understandings of the structure, mechanisms, and controllability of learning processes.

Discussion

This review contributes to contemporary discussions in the learning sciences by offering a conceptually oriented reinterpretation of physical education as a learning process. Drawing on established constructs from learning theory—such as feedback, formative assessment, adaptive regulation, and learning trajectories—it demonstrates how physical education can be systematically analyzed without reducing learning to normative performance indicators or isolated instructional techniques. By prioritizing conceptual integration and theoretical alignment, the review seeks to facilitate cumulative dialogue between physical education research and broader frameworks of learning theory.

The discussion of the results of this narrative review should begin with a synthesis of its central argument: physical education can be conceptualized as a learning system that operates according to general principles of learning theory. This perspective makes it possible to integrate regional models of physical education into the international discourse of learning sciences and to overcome the traditional opposition between motor and cognitive learning (Sfard, 1998; Khudolii, 2019; Khudolii et al., 2020).

It is important to emphasize that the interpretation of physical education as a learning system proposed in this article is not based solely on theoretical considerations. Rather, it has emerged from long-term pedagogical research in which modeling of the learning process, pedagogical control, and classification of learning states were operationalized and empirically tested in school settings.

Within these studies, learning outcomes were conceptualized not as isolated summative indicators but as dynamic learning states that change under the influence of regulatory pedagogical decisions. Models developed using discriminant and regression analysis made it possible to describe and predict the dynamics of motor skill formation and to optimize instructional influences with consideration of individual learner characteristics.

Thus, the concept of a learning system in physical education reflects an empirically verified logic of instructional organization in which feedback and regulation play a central role. In this sense, physical education can be regarded as an example of an adaptive learning system with direct relevance for the development of contemporary learning theory.

Physical Education Between Applied Practice and Learning Theory

One of the key points of discussion concerns the status of physical education within educational sciences. In many international publications, physical education is treated primarily as an applied field oriented toward health or physical activity outcomes, while its learning potential remains insufficiently conceptualized (Kirk, 2010; Bailey, 2006). The materials analyzed in this review indicate that such a reduction is methodologically limiting.

The model-based approach demonstrates that physical education includes all core elements of a learning process: learning goals, structured instructional content, feedback mechanisms, and regulation of instructional influences. This makes it possible to view physical education not as a supplementary discipline but as a full-fledged learning domain capable of contributing to the development of learning theory (Biggs, 1996; Ivashchenko, 2016; Khudolii, 2019).

Interpreting Regional Models in an International Context

An important aspect of the discussion concerns the translational value of regional research. The Ukrainian tradition of modeling physical education emerged in response to specific educational constraints and practical needs. However, the analysis shows that these models exhibit a high degree of methodological alignment with international approaches in learning theory (Hattie & Timperley, 2007; Ivashchenko, 2020).

In particular, the emphasis on pedagogical control as a feedback mechanism and the use of state classification for instructional differentiation fully correspond to contemporary conceptions of adaptive learning and formative assessment. This allows regional models to be interpreted not as local cases but as empirically grounded examples of learning system implementation in real educational contexts (Black & Wiliam, 1998; Iermakov et al., 2021).

Modeling and the Limits of Generalization

At the same time, the model-based approach has limitations that require critical reflection. First, any model represents a simplification of the real learning process and cannot fully capture the complexity of individual and social factors in learning. Second, models developed within a specific educational context require careful adaptation when transferred to other educational systems (Reigeluth, 2013).

In this regard, it is important to emphasize that the value of models lies not in their universality but in their heuristic capacity. Models help structure the learning process, identify critical parameters, and support evidence-informed pedagogical decision-making. From the perspective of learning theory, this is consistent with the understanding of models as tools for thinking rather than rigid instructional prescriptions (Davis & Sumara, 2006; Khudolii, 2019; Ivashchenko, 2020).

Pedagogical Control: Between Assessment and Learning

A separate issue concerns the interpretation of pedagogical control. In traditional pedagogical practice, control is often associated with summative assessment or selection. In the model-based approach analyzed in this article, control serves a fundamentally different function: it operates as a mechanism for regulating the learning process (Ivashchenko et al., 2019; Ivashchenko, 2020).

This brings physical education closer to contemporary theories of formative assessment, in which data on learning outcomes are used to adapt instructional design. From a discussion perspective, this raises the issue of revising traditional assessment practices in physical education and aligning them with learning goals (Hattie & Timperley, 2007; Khudolii et al., 2020).

Although the concept of teaching styles in physical education proposed in Teaching Physical Education convincingly demonstrates how the distribution of pedagogical decisions influences students' autonomy, the classical model remains largely descriptive with respect to feedback mechanisms. In particular, it provides limited tools for operationalizing learning states and learning data required for adaptive regulation of instruction. Combining the spectrum of teaching styles with model-oriented approaches to pedagogical control enables a shift from stylistic typologies to managed adaptive learning systems.

Contribution of Motor Learning to Learning Sciences

The results of the review also allow discussion of a broader issue—the role of motor learning in the development of learning sciences. Physical education, due to the high observability and measurability of learning outcomes, provides unique conditions for studying learning processes, feedback, and adaptation (Schmidt & Lee, 2019; Ivashchenko, 2020).

In this sense, motor learning can be regarded not as a peripheral field but as an important source of empirical and theoretical insights for general learning theory. This opens perspectives for interdisciplinary research integrating physical education, cognitive psychology, pedagogy, and educational measurement (Khudolii et al., 2025).

Transferability and Boundary Conditions

The applicability of the proposed learning system model depends on a number of conditions. Effective implementation requires access to basic assessment tools, sufficient time for instructional regulation based on feedback, and teachers' readiness to interpret learning data. In educational contexts where systematic measurement or instructional autonomy is lacking, the model performs primarily a heuristic rather than a fully operational function. This underscores the need to align learning systems with available resources and institutional conditions.

Directions for Further Reflection

The discussion also outlines directions for further research. In particular, the following areas require development:

- integrated models combining motor and cognitive learning outcomes;
- empirical studies of adaptive learning systems in physical education;
- comparative studies examining the applicability of model-based approaches across different educational contexts.

Such directions will not only deepen theoretical understanding of learning but also strengthen the position of physical education within the interdisciplinary field of learning sciences (OECD, 2019; UNESCO, 2015).

Conclusions and Implications for Learning Research

In this narrative review, physical education has been reconceptualized as a learning system that operates according

to general principles of learning theory. The analysis of regional and international approaches to modeling the learning process demonstrates that physical education is not a peripheral or auxiliary domain of education but constitutes a legitimate field within the learning sciences, characterized by its own learning goals, regulatory mechanisms, and measurable learning outcomes.

A central conclusion of the review is that modeling provides a conceptual framework for integrating diverse components of physical education—learning content, instructional conditions, individual learner characteristics, and pedagogical control—into a single controllable system. Within such a system, learning outcomes are interpreted as dynamic states of learning, and pedagogical decisions are grounded in feedback data rather than intuitive or purely normative assumptions.

The regional experience of modeling physical education developed within the Ukrainian pedagogical tradition illustrates how learning systems can function effectively under conditions of limited resources and high variability in learner characteristics. At the same time, analysis of the international scholarly discourse reveals a high degree of methodological compatibility between this experience and contemporary approaches in learning theory, particularly adaptive learning, formative assessment, and evidence-based instructional design. This compatibility supports the feasibility and value of integrating regional developments into the global theoretical context.

From the perspective of learning theory, particular significance lies in interpreting pedagogical control as a mechanism of learning feedback. This approach strengthens the learning-oriented nature of physical education, enhances the adaptivity of the instructional process, and creates conditions for the individualization of learning trajectories. The use of classification models to identify states of learning readiness further highlights the potential of physical education as a laboratory for investigating controllable learning systems.

For learning theory, the findings of this review have several important implications. First, they expand the scope of the learning sciences by incorporating the motor domain, thereby reducing the conceptual divide between cognitive, procedural, and physical learning. Second, they demonstrate that learning systems with a high level of operationalized variables can serve as an effective basis for testing theoretical assumptions about feedback, adaptation, and instructional control. Third, they underscore the importance of an interdisciplinary approach that integrates pedagogy, learning psychology, and educational measurement.

Future research should focus on the development of integrated learning models that combine motor, cognitive, and social outcomes, as well as on the empirical validation of adaptive learning systems across diverse educational contexts. In this process, physical education may play a key role as a domain in which learning processes are directly observable, measurable, and controllable.

Ethics Approval

Ethical approval was not required for this study because it was based exclusively on secondary or fully anonymized data.

Informed Consent

Not applicable.

Data Availability Statement

Data availability is not applicable to this article as no new data were created or analyzed.

Declaration on the Use of Artificial Intelligence

During the preparation of this article, artificial intelligence tools were used as auxiliary means for language editing, stylistic refinement, and text structuring. Artificial intelligence was not used for generating scientific data, analyzing empirical results, or formulating scientific conclusions. All conceptual positions, interpretations, and conclusions are the result of the authors' intellectual work, and the authors bear full responsibility for the content of the publication.

Funding

No external funding was received for this study.

Conflict of Interest

The authors declare no conflicts of interest.

References

- Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.). (2000). *How People Learn: Brain, Mind, Experience, and School*. National Academies Press.
- Sawyer, R.K. (Ed.). (2014). *The Cambridge Handbook of the Learning Sciences* (2nd ed.). Cambridge University Press.
- Schmidt, R.A., & Lee, T.D. (2019). *Motor Learning and Performance: From Principles to Application* (6th ed.). Human Kinetics.
- Bailey, R. (2006). Physical Education and Sport in Schools: A Review of Benefits and Outcomes. *Journal of School Health*, 76(8), 397-401. <https://doi.org/10.1111/j.1746-1561.2006.00132.x>
- Kirk, D. (2010). *Physical Education Futures*. Routledge. <https://doi.org/10.4324/9780203874622>
- World Health Organization. (2020). *WHO Guidelines on Physical Activity and Sedentary Behaviour*. WHO.
- van Sluijs, E.M. F., Ekelund, U., Crochemore-Silva, I., et al. (2021). Physical Activity Behaviours in Adolescence: Current Evidence and Opportunities for Intervention. *The Lancet Child & Adolescent Health*, 5(7), 451-460.
- OECD. (2019). *Making Physical Education Dynamic and Inclusive for 2030: International Curriculum Analysis*. OECD Publishing.
- Biggs, J. (1996). Enhancing Teaching Through Constructive Alignment. *Higher Education*, 32(3), 347-364. <https://doi.org/10.1007/BF00138871>
- Reigeluth, C.M. (Ed.). (2013). *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory* (Vol. 2). Routledge.
- Sfard, A. (1998). On Two Metaphors for Learning and the Dangers of Choosing Just One. *Educational Researcher*, 27(2), 4-13. <https://doi.org/10.3102/0013189X027002004>

- Greeno, J.G. (1998). The Situativity of Knowing, Learning, and Research. *American Psychologist*, 53(1), 5-26. <https://doi.org/10.1037/0003-066X.53.1.5>
- Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice*, 5(1), 7-74. <https://doi.org/10.1080/0969595980050102>
- Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, 77(1), 81-112. <https://doi.org/10.3102/003465430298487>
- Illeris, K. (Ed.). (2018). *Contemporary Theories of Learning: Learning Theorists ... in Their Own Words* (2nd ed.). Routledge.
- Merrill, M.D. (2002). First Principles of Instruction. *Educational Technology Research and Development*, 50(3), 43-59. <https://doi.org/10.1007/BF02505024>
- Baumeister, R.F., & Leary, M.R. (1997). Writing Narrative Literature Reviews. *Review of General Psychology*, 1(3), 311-320. <https://doi.org/10.1037/1089-2680.1.3.311>
- Grant, M.J., & Booth, A. (2009). A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies. *Health Information & Libraries Journal*, 26(2), 91-108. <https://doi.org/10.1111/j.1471-1842.2009.00848.x>
- Green, B.N., Johnson, C.D., & Adams, A. (2006). Writing Narrative Literature Reviews for Peer-Reviewed Journals: Secrets of the Trade. *Journal of Chiropractic Medicine*, 5(3), 101-117.
- Davis, B., & Sumara, D. (2006). *Complexity and Education: Inquiries Into Learning, Teaching, and Research*. Lawrence Erlbaum.
- Sadler, D.R. (1989). Formative Assessment and the Design of Instructional Systems. *Instructional Science*, 18(2), 119-144. <https://doi.org/10.1007/BF00117714>
- Mosston, M., & Ashworth, S. (2008). *Teaching Physical Education* (6th ed.). Pearson.
- Zimmerman, B.J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, 41(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2
- Nicol, D.J., & Macfarlane-Dick, D. (2006). Formative Assessment and Self-Regulated Learning: A Model and Seven Principles of Good Feedback Practice. *Studies in Higher Education*, 31(2), 199-218. <https://doi.org/10.1080/03075070600572090>
- Khudolii, O.M. (2019). Research Program: Modeling of Young Gymnasts' Training Process. *Physical Education Theory and Methodology*, 19(4), 168-178. <https://doi.org/10.17309/tmfv.2019.4.02>
- Ivashchenko, O.V. (2016). *Modeling the process of physical education of schoolchildren (Modeliuvannia protsesu fizychnoho vykhovannia shkoliariv)*. Kharkiv, Ukraine: OVS.
- Ivashchenko, O. (2020). Research Program: Modeling of Motor Abilities Development and Teaching of Schoolchildren. *Physical Education Theory and Methodology*, 20(1), 32-41. <https://doi.org/10.17309/tmfv.2020.1.05>
- Ivashchenko, O.V., Nosko, M.O., Nosko, Y.M., & Chernenko, S.O. (2019). Pattern Recognition: Description of Modes of Teaching Boys Aged 7 Throwing a Small Ball at a Vertical Target. *Physical Education Theory and Methodology*, 19(3), 130-138. <https://doi.org/10.17309/tmfv.2019.3.04>
- Iermakov, S., Khudolii, O., & Chupikhin, D. (2021). Discriminant Analysis: Impact of the Number of Repetitions on the Effectiveness of Teaching Boys Aged 7 Throwing a Small Ball. *Journal of Learning Theory and Methodology*, 2(2), 75-81. <https://doi.org/10.17309/jltm.2021.2.04>
- Mugurdinova, I., & Iermakov, S. (2022). Pattern Recognition: Effectiveness of Teaching Boys Aged 14 the Press Headstand and Handstand. *Journal of Learning Theory and Methodology*, 3(1), 11-17. <https://doi.org/10.17309/jltm.2022.1.02>
- Khudolii, O., Kapkan, O., Harkusha, S., Marchenko, S., & Veremeenko, V. (2020). Motor Skills Development: Optimization of Teaching Boys Aged 15 Press Headstand and Handstand. *Physical Education Theory and Methodology*, 20(1), 42-48. <https://doi.org/10.17309/tmfv.2020.1.06>
- Khudolii, O., Iermakov, S., & Bartik, P. (2020). Didactics: Methodological Basis of Motor Learning in Children and Adolescents. *Journal of Learning Theory and Methodology*, 1(1), 5-13. <https://doi.org/10.17309/jltm.2020.1.01>
- Khudolii, M., Ivashchenko, O., & Khudolii, O. (2025). Fundamental Movement Skills Development in Children Aged 5-12: Theory, Evidence, and Pedagogical Models. *Physical Education Theory and Methodology*, 25(6), 1456-1470. <https://doi.org/10.17309/tmfv.2025.6.16>
- UNESCO. (2015). *Quality Physical Education (QPE): Guidelines for Policy-Makers*. UNESCO.
- Hattie, J. (2008). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. Routledge. <https://doi.org/10.4324/9780203887332>
- Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Robertson, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest*, 60(2), 290-306. <https://doi.org/10.1080/00336297.2008.10483582>
- Barnett, L.M., Lai, S.K., Veldman, S.L. C., Hardy, L.L., Cliff, D.P., Morgan, P.J., Zask, A., Lubans, D.R., & Rush, E. (2016). Correlates of Gross Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine*, 46(11), 1663-1688. <https://doi.org/10.1007/s40279-016-0495-z>
- Ivashchenko, O., Khudolii, O., Prusik, K., & Giovanis, V. (2020). Strength Abilities: Immediate and Delayed Training Effects of Orthogonal Modes of Strength Training in Boys Aged 8 Years. *Physical Education Theory and Methodology*, 20(2), 109-116. <https://doi.org/10.17309/tmfv.2020.2.07>

Моделювання фізичного виховання як навчальної системи: регіональний та міжнародний виміри

Ольга Іващенко^{1ABCD}, Олег Худолій^{1ABCD}, Микола Худолій^{1ABCD}

¹Харківська державна академія фізичної культури

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 3 табл., 38 джерел.

Обґрунтування. У сучасних дослідженнях навчання освітні процеси дедалі частіше концептуалізуються як керовані, адаптивні та зворотно пов'язані системи. Попри це, фізичне виховання нерідко розглядається як концептуально відокремлене від загальної теорії навчання й переважно трактується як прикладна або нормативно орієнтована діяльність. Така редукція обмежує можливості системного аналізу, інструкційного дизайну та інтеграції механізмів формувального оцінювання.

Мета. Метою статті є концептуальне переосмислення фізичного виховання як навчальної системи з позицій теорії навчання, а також аналіз регіональних і міжнародних підходів до моделювання навчальних процесів і педагогічної регуляції навчальних результатів.

Матеріали і методи. Дослідження виконано у форматі нарративного огляду. Його методологічну основу становить концептуальний аналіз монографічних праць і публікацій у рецензованих наукових журналах, присвячених моделюванню навчального процесу, педагогічному контролю, адаптивному навчанню та інструкційному дизайну у фізичному вихованні. Відбір джерел здійснювався за концептуально орієнтованою стратегією з метою виявлення теоретично й емпірично обґрунтованих моделей навчальних систем.

Результати. Показано, що фізичне виховання може бути інтерпретоване як структурована навчальна система, яка включає навчальні цілі, операціоналізовані результати, механізми зворотного зв'язку та регуляторні педагогічні рішення. Навчальні результати концептуалізуються як динамічні стани навчання, що змінюються залежно від організації навчального процесу. Регіональні моделі ілюструють, як педагогічний контроль і класифікація станів навчання можуть використовуватися для адаптації педагогічних впливів за умов гетерогенності учнів.

Висновки. Фізичне виховання може розглядатися як легітимна галузь теорії навчання, здатна надавати концептуально узгоджені та емпірично обґрунтовані приклади керованих і адаптивних навчальних систем. Інтеграція моторного навчання у сферу learning sciences розширює можливості міждисциплінарного аналізу навчальних процесів і сприяє подоланню розриву між когнітивними, процедурними та фізичними доменами навчання.

Ключові слова: фізичне виховання, навчальна система, теорія навчання, моделювання, педагогічний контроль, адаптивне навчання, інструкційний дизайн.

Information about the Authors:

Ivashchenko Olga: ivashchenko.olha21@gmail.com; <https://orcid.org/0000-0002-2708-5636>; Department of Theory and Methods of Physical Education, Kharkiv State Academy of Physical Culture; Klochkivska St, 99, Kharkiv, 61022, Ukraine.

Khudolii Oleg: khudolii.oleg@gmail.com; <https://orcid.org/0000-0002-5605-9939>; Department of Olympic and Professional Sports, Kharkiv State Academy of Physical Culture, Klochkivska St, 99, Kharkiv, 61022, Ukraine.

Khudolii Mykola: khudolii.mykola88@gmail.com; <https://orcid.org/0009-0002-1482-6498>; Kharkiv State Academy of Physical Culture, Klochkivska St, 99, Kharkiv, 61022, Ukraine.

Cite this article as: Ivashchenko, O., Khudolii, O., & Khudolii, M. (2026). Modeling Physical Education as a Learning System: Regional and International Perspectives. *Journal of Learning Theory and Methodology*, 7(1), 6-16. <https://doi.org/10.17309/jltm.2026.7.1.01>

Received: 21.12.2025. Accepted: 17.01.2026. Published: 30.04.2026

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>)



Epistemological Foundations of Modeling in Motor Action Research: A Narrative Review

Anatolii Lopatiev^{12ABCD}, Pavol Bartik^{3BCD} and Mirosława Cieślicka^{4BCD}

¹Bobersky Lviv State University of Physical Culture

²Centre of Mathematical Modelling of IAPMM named after Ya.S.Pidstryhach of NASU

³Matej Bel University

⁴Collegium Medicum: Bydgoszcz

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.1.03

Abstract

Background. Modeling is widely used in motor action research; however, its epistemological role remains insufficiently conceptualized. Existing approaches primarily treat modeling as a descriptive or predictive tool, overlooking its function in scientific knowledge construction.

Objectives. The aim of this study was to substantiate modeling as an epistemological mechanism of scientific cognition in motor action research and to systematize its key functions in the transition from data to knowledge.

Materials and Methods. A narrative review was conducted based on the analysis of conceptual publications, including author's works and conference materials, as well as studies addressing general principles of modeling and scientific cognition. The analytical strategy involved reconstruction of conceptual development and identification of epistemic structures underlying modeling processes.

Results. Modeling is interpreted as a mediated cognitive process that integrates analogy, analysis, synthesis, and formalization. Its epistemic functions include structuring empirical data, reducing uncertainty, establishing relationships between system elements, and enabling the transition from data to information and knowledge. Motor actions are considered as complex, hierarchical systems requiring integrative models that account for biomechanical, physiological, and cognitive components. The concept of biotechnical systems is introduced as a framework for instrumental mediation, enabling synchronized data acquisition, interpretation, and feedback-based control. A conceptual epistemic model of the transition from data to information and knowledge is proposed.

Conclusions. Modeling should be regarded as a central epistemological mechanism in motor action research, providing a theoretical and methodological basis for understanding, analyzing, and managing complex movement systems.

Keywords: modeling, epistemology, motor actions, complex systems, biotechnical systems, knowledge construction, information processing.

Introduction

Modern research in the field of physical education and sport is increasingly based on a systems approach, within which motor actions and the training process are considered as complex, hierarchically organized systems that function on the basis of mechanisms of regulation, feedback, and adaptation (Wolpert et al., 2001; Araújo et al., 2006). Such an interpretation makes it possible to describe the educational and training process as a controlled system in which the achievement of the result is determined by the coherence of structural and functional components.

At the same time, despite the active use of systems terminology and descriptive models, the question of how knowledge about such systems is formed remains insufficiently disclosed. In particular, the methodological status of modeling requires clarification: whether it is only a tool for description and analysis, or whether it acts as an independent mechanism of cognition that ensures the transition from empirical data to generalized representations of the structure and functioning of motor actions (Rowley, 2007).

In the classical understanding, modeling is associated with the construction of a simplified representation of the object of study, which makes it possible to investigate

© Lopatiev, A., Bartik, P., & Cieślicka, M., 2026.

its properties indirectly (Kawato, 1999). However, in the context of studying complex biological and biomechanical systems, such an interpretation is insufficient. Modeling acquires a broader meaning, acting as a process that includes the formation of analogies, the identification of essential variables, the establishment of relationships between system elements, and their subsequent formalization (Campos & Calado, 2009).

This becomes especially important in the analysis of human motor actions, which are characterized by a high level of complexity, multidimensionality of parameters, and interaction of heterogeneous subsystems. Under such conditions, direct investigation of the object is often limited, and obtaining knowledge is possible only through the construction and analysis of models that reflect the most essential aspects of system functioning (Sabes, 2000).

An important aspect of the modern understanding of modeling is its connection with information processes. A motor action can be considered as the result of information processing in a system, where the reduction of state uncertainty is achieved through the acquisition, transmission, and interpretation of data (Rowley, 2007). In this context, modeling acts as a means of structuring information and transforming it into knowledge that has practical significance for movement control and improving performance efficiency.

Particular attention should be paid to biotechnical systems, in which biological and technical components are combined. In such systems, the modeling process goes beyond purely theoretical description and includes the use of instrumental control tools that ensure the acquisition of data about the system state in real time. This creates conditions for the transition from parameter recording to their interpretation and further use in the control process (Kawato & Cortese, 2021; Russo et al., 2025).

In this work, modeling is considered not as a tool of description, but as an epistemological mechanism that ensures a structured transition from data to scientific knowledge in the study of motor actions.

The aim of this work is to provide a theoretical substantiation of modeling as a methodology for knowledge construction in the study of motor actions, as well as to generalize approaches to its use in the analysis of complex biological systems. In this context, the contribution of this work is the formalization of modeling as an epistemological mechanism for knowledge construction in the study of motor actions.

Materials and Methods

Methodology of the Narrative Review

This study was conducted in the format of a narrative review aimed at the conceptual reconstruction of approaches to modeling in the study of motor actions. Unlike systematic reviews, the main purpose of which is to summarize empirical results, a narrative review is oriented toward the analysis of theoretical provisions, the identification of the logic of scientific idea development, and the formation of a holistic understanding of the problem under study.

The selection of sources was carried out taking into account their conceptual significance for revealing the

epistemological aspects of modeling. The analysis included: (1) original scientific publications presenting the development of approaches to modeling motor actions; (2) works devoted to general issues of modeling theory and scientific cognition; (3) materials from scientific conferences reflecting the evolution of ideas and their validation in applied research. This approach made it possible to combine theoretical and applied levels of analysis and ensure consistency of presentation.

The analytical strategy of the study was based on the principles of conceptual synthesis. The main stages of the analysis were: reconstruction of key ideas that determine the understanding of modeling as a method of scientific cognition; identification of the epistemic functions of modeling; establishment of relationships between theoretical provisions and their application in the study of motor actions. Particular attention was paid to the alignment of concepts used in different works and their integration into a unified conceptual structure.

The methodological basis of the analysis consisted of general scientific approaches, in particular the systems approach, which makes it possible to consider motor actions as complex, hierarchically organized systems, as well as the information approach, which provides interpretation of regulation and control processes as processes of information processing. This approach is consistent with studies in which systems analysis and mathematical modeling are considered as the methodological basis for investigating processes in physical education and sport, ensuring the integration of theoretical provisions and experimental data into a unified system of knowledge (Lopatiev et al., 2017). The use of these approaches made it possible to form a coherent theoretical framework for analyzing the role of modeling in knowledge construction.

The limitations of the study are related to the specificity of the narrative review, which does not involve formalized search procedures or quantitative evaluation of sources. The selection of literature was purposeful, which may affect the representativeness of the results. At the same time, such an approach is justified given the aim of the study, which is not to provide exhaustive coverage of all publications, but to form a holistic conceptual model.

Thus, the chosen methodology provides the possibility of an in-depth theoretical analysis of modeling as an epistemological mechanism and creates a basis for integrating the obtained results within the context of the study of motor actions.

Results

Modeling as a Method of Scientific Cognition

Modeling occupies a special place among the methods of scientific cognition, as it provides the possibility of investigating complex objects and processes under conditions where their direct study is limited or impossible (Kawato, 1999; Campos & Calado, 2009; Lopatiev, 2007). In general terms, modeling can be considered as the process of constructing and analyzing a specially designed object—a model—that reflects the most essential properties of the real system and allows obtaining new knowledge about it indirectly.

One of the fundamental logical foundations of modeling is analogy. It is through establishing similarity between the object of study and its model that the transfer of knowledge from the model to the original becomes possible. Analogy is not reduced to superficial similarity but involves the identification of structural or functional correspondence between systems, enabling the representation of one system in terms of another (Hesse, 1966; Frigg & Hartmann, 2021). In this context, the model acts not as a copy of the real object but as its theoretically grounded representation, constructed on the basis of identifying key variables and relationships.

The modeling process is inseparably connected with the combination of analytical and synthetic procedures. At the analytical stage, the researcher decomposes the object, identifying its constituent elements, parameters, and factors that determine its functioning. At the synthetic stage, these elements are integrated into a coherent system, relationships between them are established, and a generalized structure of the model is formed. It is precisely the combination of analysis and synthesis that ensures the transition from empirical description to theoretical generalization (Bunge, 1973).

An important characteristic of modeling is its mediated nature. Unlike direct experimental research, where interaction with the object occurs directly, modeling involves the use of an intermediate link—the model—which serves as an instrument of cognition. This makes it possible to investigate the properties of a system under conditions where direct experimentation is difficult due to the complexity, scale, dynamism, or inaccessibility of the object (Kawato, 1999). In the case of human motor actions, such limitations are associated with the multidimensionality of parameters, variability of states, and interaction of physiological, biomechanical, and psychological processes (Wolpert et al., 2001).

Within modeling, the issue of the adequacy of the model to the object of study is important. Adequacy does not imply complete correspondence but is determined by the model's ability to reproduce those properties of the system that are essential for solving the given scientific problem (Box, 1976). Thus, any model is the result of conscious simplification, which makes it possible to focus on the key aspects of system functioning while ignoring secondary factors.

Depending on the mode of representation and the level of formalization, different types of models are distinguished, among which mathematical and simulation models occupy a special place. Mathematical models involve a rigorous quantitative description of the system in the form of equations, functions, and relationships between variables. Simulation models, in turn, make it possible to reproduce system behavior without a complete formal description, using algorithmic procedures and computational tools. In the study of complex biological systems, in particular human motor actions, simulation modeling becomes especially important, as it allows taking into account a large number of interacting factors under conditions of limited formalization (Campos & Calado, 2009; Russo et al., 2025; Lopatiev, Vlasov et al., 2017).

Thus, modeling acts not only as a technical tool of description but as a universal method of scientific cognition that ensures the transition from observation to understanding (Lopatiev, 2007). It makes it possible to

structure knowledge about complex systems, establish cause-and-effect relationships, and form theoretical representations of the mechanisms of their functioning. In the context of the study of motor actions, this opens opportunities for a deeper analysis of the processes of regulation, coordination, and adaptation that determine the effectiveness of human activity (Wolpert et al., 2001).

From Model to Knowledge: Epistemic Functions of Modeling

The transition from model to knowledge is a central problem in the methodology of scientific cognition, especially in the study of complex systems, which include human motor actions (Kawato & Cortese, 2021). In this context, modeling cannot be considered only as a tool for description or prediction, but should be interpreted as an epistemic mechanism that ensures the transformation of empirical data into structured knowledge (Giere, 2004; Rowley, 2007).

One of the key functions of modeling is the organization of the transition from data to information and further to knowledge. Data obtained in the process of observation or experiment do not possess explanatory power by themselves if they are not embedded in a certain system of relationships. The model acts as the environment in which these data acquire structure, are related to each other, and are interpreted in the context of the system under study. Thus, modeling ensures the transition from a set of fragmented measurements to a generalized understanding of the functioning of the object (Rowley, 2007).

In this process, the concept of information as a reduction of uncertainty of the system state plays an important role. Complex biological systems are characterized by a large number of possible states, and without an appropriate data structure their behavior appears random or uncontrolled. The construction of a model makes it possible to organize these states, identify the most probable scenarios, and establish regularities of transitions between them. As a result, uncertainty is reduced, and the obtained results can be interpreted as information about the system (Shannon, 1948).

Formalization is another important epistemic function of modeling. It involves the transition from qualitative description to quantitative representation of system properties. In the process of formalization, variables, parameters, and relationships between them are defined, which makes it possible to describe the system in the form of mathematical or algorithmic structures. Formalization not only increases the accuracy of description but also creates opportunities for hypothesis testing, analysis of system development scenarios, and prediction of its behavior (Bunge, 1973).

An important aspect is also the establishment of relationships between system elements. In complex systems, individual parameters cannot be considered in isolation, since their values and dynamics are determined by interaction with other elements. Modeling makes it possible to identify these interrelationships, represent them in a structured form, and assess their influence on the overall result. It is precisely through the establishment of such relationships that the model acquires explanatory power and ceases to be merely a descriptive scheme (Wolpert et al., 2001).

Of particular importance is the ability of the model to integrate heterogeneous data. In the study of motor

actions, these may include biomechanical, physiological, and psychophysiological indicators that reflect different aspects of system functioning. Without a model, these data remain fragmented and do not allow obtaining a holistic understanding of the object. Modeling ensures their integration, making it possible to consider the system as a whole and identify interdependencies between its subsystems (Russo et al., 2025).

In the context of human motor actions, modeling also performs the function of complexity reduction. Biological systems are characterized by a high level of variability and nonlinearity, which complicates their direct analysis. The model makes it possible to reduce this complexity by identifying key parameters and discarding secondary factors. Such reduction does not imply a loss of meaning; on the contrary, it contributes to a clearer understanding of the mechanisms of system functioning (Campos & Calado, 2009).

The proposed structure can be defined as an epistemic model of the transition “data → information → knowledge” in the modeling process, which includes three interrelated levels: (1) data structuring; (2) formation of information through uncertainty reduction; (3) knowledge construction through formalization and integration of relationships between system elements. Such an interpretation makes it possible to present modeling as a holistic mechanism of cognition rather than a set of separate analytical procedures (Rowley, 2007) (Table 1).

Thus, modeling acts as a multifunctional epistemic instrument that ensures data structuring, uncertainty reduction, knowledge formalization, and the establishment of cause-and-effect relationships. These functions determine its key role in the study of motor actions, where the complexity of the object requires the use of mediated methods of cognition. In this sense, modeling should be considered not only as an auxiliary method but as a central mechanism for constructing scientific knowledge about motor systems (Kawato & Cortese, 2021) (Table 2).

Modeling of Motor Actions as Complex Systems

Human motor actions belong to the class of complex biological systems characterized by multidimensionality of parameters, hierarchical organization, and dynamic interaction with the environment (Wolpert et al., 2001; Araújo et al., 2006). This nature of the object necessitates

the use of models capable of reflecting not only individual components of movement but also the system of relationships between them, which determines the final result of activity as the behavior of a complex system.

One of the key characteristics of motor actions is their hierarchical nature. The formation of movement occurs at different levels of organization—from central control mechanisms to executive structures that implement motor commands. At each of these levels, information is processed, movement parameters are refined, and adaptation to performance conditions occurs (Kawato, 1999). Modeling makes it possible to represent this hierarchy in the form of interconnected subsystems, each of which performs a specific function in achieving the target result.

Another important property of motor actions is their multidimensionality (Lopatiev et al., 2009). The effectiveness of movement execution is determined not by a single parameter but by a set of biomechanical, physiological, and psychophysiological characteristics. This complicates analysis, as a change in one parameter may affect others, forming a complex system of interdependencies. Under such conditions, the model serves as a means of integrating heterogeneous parameters into a unified system, allowing the assessment of their combined influence on the result (Campos & Calado, 2009; Lopatiev et al., 2009).

A significant aspect is also the dynamic nature of motor actions. Unlike static systems, a motor action unfolds over time, and its parameters change depending on the internal state of the organism and external conditions. This requires the use of models that take into account the temporal structure of the process, including the phase organization of movement, the sequence of actions, and variability of execution. Modeling makes it possible to analyze not only individual moments of movement but also its development over time, which is critically important for understanding regulatory mechanisms (Sabes, 2000; Russo et al., 2025).

Control of motor actions is carried out on the basis of feedback and regulation principles. Information about the current state of the system is transmitted to control centers, where it is compared with the set goal, after which corrective actions are formed (Kawato, 1999). In this process, an important role is played by the system’s ability to maintain stability of functioning under changing environmental conditions, which is related to the concepts of homeostasis and adaptation. Modeling makes it possible to describe these

Table 1. Epistemic model of the transition “data → information → knowledge”

Level	Characteristic	Modeling function	Result
Data	Unorganized measurements	Structuring; parameter selection	Organized data
Information	Data with reduced uncertainty	Establishing relationships; interpretation	Meaningful relationships
Knowledge	Integrated system of relationships	Formalization; generalization	Theoretical model

Table 2. Epistemic functions of modeling in motor action research

Function	Essence	Epistemic result
Structuring	Organization of data	Elimination of randomness
Uncertainty reduction	Identification of regularities	Transition to information
Formalization	Quantitative representation	Hypothesis testing
Integration	Combination of heterogeneous data	Holistic knowledge
Complexity reduction	Identification of key variables	System controllability

mechanisms in the form of closed control loops that ensure the achievement of the target result.

A particular complexity lies in the fact that motor actions are not purely mechanical processes. They include psychophysiological components related to motivation, attention, level of activation, and other factors that directly influence performance outcomes. This means that models built exclusively on mechanistic assumptions are insufficient for an adequate description of motor systems. It is necessary to consider the integrity of the biological system in which physical, physiological, and psychological processes interact (Araújo et al., 2006).

In this context, it is important to understand a motor action as a goal-directed system in which the goal acts as a system-forming factor. It is precisely the presence of a goal that determines the structure of interactions between system elements, the selection of movement parameters, and the nature of regulatory processes. Modeling makes it possible to formalize this goal-directedness by representing it in the form of performance criteria, optimization functions, or other parameters that reflect the achievement of the result (Wolpert et al., 2001).

Thus, modeling of motor actions as complex systems involves taking into account their hierarchical organization, multidimensionality, dynamism, and regulatory mechanisms. It provides the possibility of transitioning from the description of individual parameters to understanding the holistic structure and functioning of the system, which is a necessary condition for further analysis and interpretation of motor activity (Russo et al., 2025).

Biotechnical Systems and Instrumental Mediation of Knowledge

One of the most important conditions for the practical implementation of modeling in the study of motor actions is the inclusion of technical means in the process of data acquisition, processing, and interpretation. This leads to the formation of biotechnical systems in which biological components (the human as the object of study) and technical means that ensure the recording, transmission, and analysis of information are combined. Within this approach, modeling goes beyond purely theoretical description and acquires an instrumentally mediated character (Kawato & Cortese, 2021; Lopatiev, Vlasov et al., 2017).

In this context, modeling acquires the features of instrumental epistemology, within which knowledge is formed through the interaction of the biological system and the technical environment of measurement and analysis. Within this study, this approach is defined as an instrumental-epistemic model of modeling motor actions (Winsberg, 2010).

A biotechnical system can be considered as an integrated structure that includes the object of study, measurement and analysis tools, as well as the subject of interpretation. It is important to emphasize that technical means are not neutral instruments for recording data. They determine the mode of information representation, its accuracy, temporal resolution, and possibilities for further processing. Thus, the technical component becomes an active element of the cognition process, influencing the formation of the model of the system under study (Kawato & Cortese, 2021).

Of particular importance is the synchronous collection of data of different nature. In the study of motor actions, this may include the simultaneous recording of biomechanical

movement parameters, physiological indicators (for example, heart rate), and performance outcomes. Such synchronization makes it possible to consider the system in dynamics, establish temporal relationships between different parameters, and identify patterns that remain inaccessible in the isolated analysis of individual indicators (Russo et al., 2025).

Instrumental mediation of modeling creates conditions for the transition from measurement to interpretation. Data obtained using technical means do not possess explanatory power by themselves if they are not included in a certain model structure. It is the model that determines which parameters are essential, how they are related to each other, and how their changes affect performance outcomes. In this process, signals recorded by technical means are transformed into information that carries meaning (Rowley, 2007).

The next stage is the use of the obtained information in the control process. Biotechnical systems make it possible to implement closed feedback loops in which measurement results directly influence the correction of motor actions. This can occur both in the form of external control (by a coach or researcher) and through the formation of internal self-regulation mechanisms in the athlete. Thus, modeling becomes not only a means of analysis but also an instrument of active influence on the system (Kawato, 1999).

An important aspect of biotechnical systems is their ability to integrate different levels of organization of motor activity. Technical means make it possible to simultaneously account for parameters that reflect both the mechanical characteristics of movement and the functional state of the organism. This creates prerequisites for constructing comprehensive models that more adequately reflect the real structure of motor action and allow identifying relationships between different subsystems (Campos & Calado, 2009).

In this context, a special role is played by the subject of interpretation—the researcher or coach—who analyzes the obtained data and forms management decisions on their basis. It is at this stage that the final transition from information to knowledge occurs, when modeling results are used to explain the mechanisms of system functioning and optimize its activity. Thus, the biotechnical system includes not only technical and biological components but also a cognitive level associated with the decision-making process (Kawato & Cortese, 2021).

Thus, biotechnical systems act as the environment in which the epistemic functions of modeling are realized. They ensure the instrumental mediation of cognition, integration of heterogeneous data, their interpretation, and their use in the process of controlling motor actions (Lopatiev et al., 2017). This makes it possible to consider modeling not only as a theoretical method but as a practical mechanism for knowledge construction directly related to the effectiveness of human activity (Russo et al., 2025).

Discussion

The obtained results make it possible to consider modeling not as an auxiliary research tool but as a central epistemological mechanism that ensures the construction of knowledge about complex motor systems (Kawato & Cortese, 2021; Lopatiev, 2007). Unlike approaches in which modeling is used primarily for describing or predicting individual

parameters, in this work it is interpreted as a process that includes the formation of analogies, identification of essential variables, establishment of structural relationships, and their formalization. It is precisely this interpretation that allows the transition from fragmented analysis to a holistic understanding of system functioning.

In this context, it is essential to distinguish between the descriptive and epistemic functions of modeling. The descriptive function is associated with reproducing the characteristics of the object, whereas the epistemic function is related to constructing knowledge about the mechanisms of its functioning. The results of the analysis show that it is the epistemic function that determines the potential of modeling in the study of motor actions, as it enables the establishment of cause-and-effect relationships, integration of heterogeneous data, and formation of generalized representations of the system (Bunge, 1973).

An important result is the substantiation of the role of the informational dimension of modeling. Motor action is considered as a system in which the reduction of uncertainty is achieved through the acquisition, processing, and interpretation of information. In this process, the model acts as a structure that organizes data and transforms them into information suitable for further use (Shannon, 1948; Rowley, 2007). This approach makes it possible to reinterpret the role of feedback and regulation, considering them as information processes that ensure stability and efficiency of system functioning.

The consideration of motor actions as complex systems confirms the need to move beyond purely mechanistic models that do not account for multilevel organization and psychophysiological aspects of activity (Araújo et al., 2006). The proposed approach, based on the integration of biomechanical, physiological, and cognitive components, allows for a more adequate representation of the real structure of motor action. In this context, modeling acts as a means of synthesizing different levels of analysis, which is a necessary condition for constructing a coherent scientific picture (Wolpert et al., 2001).

Of particular importance is the introduction of the concept of a biotechnical system as the environment for the implementation of modeling. The inclusion of technical means in the research process makes it possible to obtain synchronized data of different nature, significantly increasing the informativeness of analysis. At the same time, technical means not only expand measurement capabilities but also influence the process of cognition itself, determining the mode of representation and interpretation of information. This makes it possible to consider biotechnical systems as integrated structures in which measurement, modeling, and control are combined (Kawato & Cortese, 2021; Lopatiev et al., 2017).

The obtained results have important implications for understanding the processes of controlling motor actions. Modeling makes it possible to move from an intuitive approach to control toward evidence-based decisions grounded in the analysis of system structure and its dynamics. This creates prerequisites for increasing the effectiveness of the educational and training process, as it allows taking into account individual characteristics of the athlete, adapting load parameters, and optimizing conditions for performing motor actions (Russo et al., 2025).

At the same time, the results of the study indicate the need for further development of modeling methodology toward

increasing its level of formalization and integration with modern information technologies. In the applied dimension, this opens opportunities for combining the proposed epistemic model with methods of mathematical modeling already used in physical education and sport, including factorial experiments, logistic models, and discriminant analysis, which make it possible to formalize processes of learning and control of motor actions (Lopatiev et al., 2017). Particularly promising is the integration of mathematical and simulation modeling with methods of big data processing, which expands the possibilities for analyzing complex systems and increases the accuracy of the obtained results (Kawato & Cortese, 2021).

The proposed approach defines modeling as a fundamental epistemological mechanism in the study of motor actions, which fundamentally differs from system-organizational and applied approaches by focusing on the processes of knowledge construction rather than solely on the structure or functioning of the system.

Thus, the conducted analysis makes it possible to consider modeling as a key element of scientific research on motor actions, ensuring not only their description but also explanation and prediction of their functioning. In this sense, modeling acts as a universal tool for knowledge integration that combines theoretical and applied aspects of research and creates a basis for further development of the science of human motor activity (Wolpert et al., 2001).

Limitations and Future Research Perspectives

In addition to the methodological limitations inherent in narrative reviews, the proposed epistemic model of the transition “data → information → knowledge” has conceptual limitations that should be taken into account.

First, the model is a theoretical abstraction and has not been empirically verified within a single experimental system. Although it integrates established principles of modeling and scientific cognition, its applicability to different types of motor actions requires further empirical validation.

Second, modeling as an epistemic process is inevitably associated with the reduction of system complexity through the selection of key variables and relationships. Such reduction, necessary for analysis and formalization, may lead to a partial loss of system properties and limit the completeness of its representation.

Third, in the context of biotechnical systems, the process of knowledge construction depends on the characteristics of measurement tools, data collection procedures, and analytical approaches. These factors influence not only the quality of data but also the structure and interpretation of models.

Future research perspectives are related to the empirical verification of the proposed epistemic model, in particular through the development of operational indicators for each stage of the transition “data → information → knowledge.” It is also promising to combine the conceptual approach with methods of mathematical and simulation modeling, as well as with modern big data processing technologies, which will increase the accuracy and reproducibility of results.

Conclusions

Modeling in the study of motor actions should be considered as an epistemological mechanism that ensures

the transition from empirical data to structured scientific knowledge through the formation of analogies, identification of variables, and establishment of system relationships.

The epistemic function of modeling is realized through the organization of the transition “data → information → knowledge,” reduction of uncertainty, and formalization of interactions between elements of a complex system.

Human motor actions as complex, hierarchically organized systems require the use of models that integrate biomechanical, physiological, and cognitive components and reflect mechanisms of regulation and adaptation.

Biotechnical systems provide instrumental mediation of modeling, integration of heterogeneous data, and implementation of closed feedback loops, which shifts modeling from the analytical to the control level.

Considering modeling as a central mechanism of knowledge construction creates a methodological basis for increasing the validity of motor action research and the effectiveness of practices for controlling motor activity.

Ethics Approval

This study is a narrative review and does not involve human participants or experimental procedures. Therefore, ethical approval was not required.

Informed Consent

This study does not involve human participants. Therefore, informed consent was not applicable.

Data Availability

No new data were generated or analyzed in this study. All information is derived from previously published sources cited in the manuscript.

AI Transparency Statement

AI-assisted tools were used solely for language editing and structuring of the manuscript. The authors take full responsibility for the content, interpretation, and conclusions presented in this work.

References

- Wolpert, D. M., Ghahramani, Z., & Flanagan, J. R. (2001). Perspectives and problems in motor learning. *Trends in Cognitive Sciences*, 5(11), 487–494. [https://doi.org/10.1016/S1364-6613\(00\)01773-3](https://doi.org/10.1016/S1364-6613(00)01773-3)
- Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, 7(6), 653–676. <https://doi.org/10.1016/j.psychsport.2006.07.002>
- Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science*, 33(2), 163–180. <https://doi.org/10.1177/0165551506070706>
- Kawato, M. (1999). Internal models for motor control and trajectory planning. *Current Opinion in Neurobiology*, 9(6), 718–727. [https://doi.org/10.1016/S0959-4388\(99\)00028-8](https://doi.org/10.1016/S0959-4388(99)00028-8)
- Campos, F. M. M. O., & Calado, J. M. F. (2009). Approaches to human arm movement control—A review. *Annual Reviews in Control*, 33(1), 69–77. <https://doi.org/10.1016/j.arcontrol.2009.03.001>
- Sabes, P. N. (2000). The planning and control of reaching movements. *Current Opinion in Neurobiology*, 10(6), 740–746. [https://doi.org/10.1016/S0959-4388\(00\)00149-5](https://doi.org/10.1016/S0959-4388(00)00149-5)
- Kawato, M., & Cortese, A. (2021). From internal models toward metacognitive AI. *Biological Cybernetics*, 115(5), 415–430. <https://doi.org/10.1007/s00422-021-00904-7>
- Russo, M., Maselli, A., Sternad, D., & Pezzulo, G. (2025). Predictive strategies for the control of complex motor skills: Recent insights into individual and joint actions. *Current Opinion in Behavioral Sciences*. <https://doi.org/10.1016/j.cobeha.2025.101519>
- Lopatiev, A., Ivashchenko, O., Khudoliy, O., Pjanylo, Y., Chernenko, S., & Yermakova, T. (2017). Systemic approach and mathematical modeling in physical education and sports. *Journal of Physical Education and Sport*, 17(Suppl. 1), 146–155. <https://doi.org/10.7752/jpes.2017.s1023>
- Lopatiev, A. O. (2007). Modeling as a methodology of cognition [in Ukrainian]. *Physical Education Theory and Methodology*, (8), 4–10. <https://www.tmfv.com.ua/journal/article/view/334>
- Hesse, M. (1966). *Models and analogies in science*. University of Notre Dame Press
- Frigg, R., & Hartmann, S. (2021). Models in science. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy*. <https://plato.stanford.edu/entries/models-science/>
- Bunge, M. (1973). Method, model and matter. Reidel.
- Box, G. E. P. (1976). Science and statistics. *Journal of the American Statistical Association*, 71(356), 791–799. <https://doi.org/10.1080/01621459.1976.10480949>
- Lopatiev, A. O., Vlasov, A. P., & Demichkovskiy, A. P. (2017). Modeling Biotechnical Systems in Sports. *Physical Education Theory and Methodology*, 17(4), 184–190. <https://doi.org/10.17309/tmfv.2017.4.1203>
- Giere, R. N. (2004). How models are used to represent reality. *Philosophy of Science*, 71(5), 742–752. <https://doi.org/10.1086/425063>
- Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27, 379–423.
- Lopatiev, A. O., Dziubachyk, M. I., & Smilnianyn, S. M. (2009). Modeling features of the “shooter–weapon–target” system [in Ukrainian]. *Physical Education Theory and Methodology*, (5), 37–42. <https://www.tmfv.com.ua/journal/article/view/533>
- Winsberg, E. (2010). *Science in the age of computer simulation*. University of Chicago Press.

Епістемологічні засади моделювання у дослідженні рухових дій: наративний огляд

Анатолій Лопатьєв^{1,2ABCD}, Павол Бартік^{3BCD}, Мирослава Цислицька^{4BCD}

¹Львівський державний університет фізичної культури імені Івана Боберського

²Центр математичного моделювання ІППММ імені Я.С. Підстригача

³Університет Матея Беля

⁴Медичний колегіум: Бидгощ

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 2 табл., 19 джерел.

Обґрунтування. Моделювання широко використовується у дослідженні рухових дій; однак його епістемологічна роль залишається недостатньо концептуалізованою. Існуючі підходи переважно розглядають моделювання як описовий або прогностичний інструмент, ігноруючи його функцію у побудові наукового знання.

Мета. Метою дослідження є обґрунтування моделювання як епістемологічного механізму наукового пізнання у дослідженні рухових дій та систематизація його ключових функцій у переході від даних до знання.

Матеріали і методи. Проведено наративний огляд на основі аналізу концептуальних публікацій, включаючи авторські роботи та матеріали конференцій, а також досліджень, присвячених загальним принципам моделювання та наукового пізнання. Аналітична стратегія передбачала реконструкцію концептуального розвитку та ідентифікацію епістемічних структур, що лежать в основі процесів моделювання.

Результати. Моделювання інтерпретується як опосередкований когнітивний процес, що інтегрує аналогію, аналіз, синтез і формалізацію. Його епістемічні функції включають структурування емпіричних даних, зменшення невизначеності, встановлення зв'язків між елементами системи та забезпечення переходу від даних до інформації і знання. Рухові дії розглядаються як складні ієрархічні системи, що потребують інтегративних моделей, які враховують біомеханічні, фізіологічні та когнітивні компоненти. Запропоновано поняття біотехнічних систем як рамкової конструкції інструментального опосередкування, що забезпечує синхронізований збір даних, їх інтерпретацію та керування на основі зворотного зв'язку. Запропоновано концептуальну епістемічну модель переходу «дані → інформація → знання».

Висновки. Моделювання слід розглядати як центральний епістемологічний механізм у дослідженні рухових дій, що забезпечує теоретико-методологічну основу для розуміння, аналізу та керування складними руховими системами.

Ключові слова: моделювання, епістемологія, рухові дії, складні системи, біотехнічні системи, побудова знання, обробка інформації.

Information about the Authors:

Lopatiev Anatolii: lopatiiv@gmail.com; <https://orcid.org/0000-0002-4474-7558>; Ivan Bobersky Lviv State University of Physical Culture, Centre of Mathematical Modelling of IAPMM named after Ya.S.Pidstryhach of NASU, Department of Shooting and Technical Sports, Kostiushka St, 11, Lviv, 79007, Ukraine.

Bartik Pavol: pavol.bartik@umb.sk; <https://orcid.org/0000-0002-2087-7876>; Matej Bel University, Department of Physical Education and Sports, Tajovského 40, 97401 Banská Bystrica, Slovakia.

Cieślicka Mirosława: cudaki@op.pl; <https://orcid.org/0000-0002-0407-2592>; Collegium Medicum: Bydgoszcz, Kujawsko Pomorskie Chodkiewiczza St, 30, 85-064 Bydgoszcz, Poland.

Cite this article as: Lopatiev, A., Bartik, P., & Cieślicka, M. (2026). Epistemological Foundations of Modeling in Motor Action Research: A Narrative Review. *Journal of Learning Theory and Methodology*, 7(1), 17-24. <https://doi.org/10.17309/jltm.2026.7.1.03>

Received: 21.03.2025. Accepted: 08.04.2026. Published: 30.04.2026

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>)



Healthy Lifestyle Program to Improve Physical Literacy and Physical Fitness of Junior High School Students: A Quasi-Experimental Approach

Nevitaningrum^{1ABCDE}, Pepep Mochamad Syafei^{1ADE}, Gumilar Mulya^{1ADE},
Trisnar Adi Prabowo^{2CD}, Oktaviarini Yahya Rahmadhanty^{3CD}
and Putu Deanita I Desta Suryani^{4CD}

¹Siliwangi University

²Muhammadiyah Brebes University

³Singaperbangsa Karawang University

⁴Yogyakarta State University

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.1.02

Abstract

Objectives. This quasi-experimental study aimed to evaluate the effectiveness of the Healthy Lifestyle Program (HLP), integrated into regular physical education classes, in enhancing physical literacy and physical fitness among junior high school students aged 13–14, while addressing sedentary behaviors associated with high screen time and limited outdoor play.

Materials and Methods. Seventy-two eligible students (mean age = 13.6 ± 0.4 years; 19 males and 17 females per group) were allocated to an experimental group (EXP; $n = 36$) or a control group (CON; $n = 36$) using a non-random assignment based on intact classes, consistent with a quasi-experimental design. The EXP group participated in the HLP, which consisted of weekly 80-minute sessions incorporating warm-up activities, motor skill activation, fitness circuits, small-sided games, classroom active breaks, and home-based physical activity assignments at a target intensity of Borg RPE 12–14, complemented by weekly healthy lifestyle education. The CON group followed the standard physical education curriculum. Physical literacy was assessed using the Indonesian-adapted Adolescent Physical Literacy Questionnaire (APLQ; Cronbach's $\alpha = 0.951$), and physical fitness was measured using the Indonesian Physical Fitness Test (TKJI; validity = 0.720; reliability = 0.920). Inter-rater reliability was high (APLQ ICC = 0.82; TKJI ICC = 0.88). Program content validity was confirmed using Aiken's V (0.94). Data were analyzed using descriptive statistics, Shapiro–Wilk tests for normality, Levene's tests for homogeneity, and MANOVA with partial η^2 effect sizes.

Results. Baseline scores were comparable between groups. The EXP group demonstrated substantial improvements in physical literacy (gain = 24.75 ± 14.52) and physical fitness (gain = 6.94 ± 2.51), whereas the CON group showed minimal change (physical literacy gain = -0.44 ± 2.18 ; physical fitness gain = 0.08 ± 0.60). MANOVA revealed a significant multivariate effect (Wilks' $\Lambda = 0.180$, $p < 0.001$), with large effect sizes for both physical literacy ($\eta^2 = 0.602$) and physical fitness ($\eta^2 = 0.785$). All statistical assumptions were met.

Conclusions. The Healthy Lifestyle Program significantly improved physical literacy and physical fitness among early adolescents. These findings support the integration of educationally grounded, multicomponent lifestyle programs into school curricula, such as Kurikulum Merdeka, to address sedentariness using accessible and contextually appropriate resources. Future research should examine longer intervention durations and more diverse socioeconomic contexts.

Keywords: healthy lifestyle program, physical literacy, physical fitness, junior high school.

Introduction

In Contemporary life, sedentary lifestyles among adolescents have become increasingly prevalent, marked by

prolonged screen time through television viewing, gaming, computer use, and extended sitting during school hours or commuting, all of which contribute to decreased physical activity and lower fitness levels (Mehtälä et al., 2020). Within the domain of Physical Education, the central issue extends beyond the goal of merely “getting students to move”;

© Nevitaningrum, N., Syafei, P. M., Mulya, G., Prabowo, T. A., Rahmadhanty, O. Y., & Suryani, P. D. I. D., 2026.



schools must build personal capacities that enable students to be willing, capable, and consistent in engaging in physical activity outside formal Physical Education lessons (Fierro-Suero et al., 2022; Estevan et al., 2023). The concept of physical literacy comprising motivation, confidence, competence, and understanding emerges as an essential educational construct linking knowledge acquisition and behavioral engagement (Yli-Piipari et al., 2021). When physical literacy is low, adolescents' motivation and confidence to participate in physical activity tend to decline, resulting in limited engagement beyond school hours (Caldwell et al., 2020; Castillo et al., 2020). Thus, physical literacy should be conceptualized not merely as an attribute but as an educational outcome that mediates behavioral transformation through structured learning experiences.

Physical literacy serves as the pedagogical foundation that connects the affective and cognitive learning domains with behavioral and physical outcomes. This integration aligns with the Self-Determination Theory (SDT), which explains how intrinsic motivation and perceived competence drive sustained participation in physical activity (Nguyen et al., 2025), and with Experiential Learning Theory (ELT), which emphasizes learning through active engagement and reflection (Lima et al., 2024; Ockerman & Bagui, 2024). The theoretical framework underpinning the integration of physical literacy and physical fitness is grounded in these theories, where physical literacy functions not just as a psychological construct but as a bridge between motivation, behavior, and fitness development. Within this framework, physical literacy operates as both a process and an outcome of learning where physical competence develops alongside self-regulation, autonomy, and reflective understanding of one's body and movements (Rudd et al., 2020; Bernhart et al., 2022; Chen et al., 2020; Lev-Arey et al., 2024).

Accordingly, the Healthy Lifestyle Program (HLP) proposed in this study is not a simple fitness regimen; it functions as an educational intervention designed to enhance learning processes that lead to behavioral transfer from the school environment to home and community contexts (Nguyen et al., 2025; Lee et al., 2025). This is an essential shift in thinking, framing the program not merely as a fitness initiative but as a pedagogical model that advances existing learning theories by integrating physical literacy as a foundational component of broader educational goals.

Moreover, this study advances educational theory by framing the Healthy Lifestyle Program (HLP) as a structured learning design that intentionally converts "in-lesson participation" into transferable self-regulation and lifestyle practices. Grounded in Self-Determination Theory, the HLP is designed to cultivate autonomy, competence, and relatedness through meaningful task design and supportive social contexts, as these psychological needs are consistently linked to self-determined forms of motivation and sustained physical activity (Nguyen et al., 2025; Mendoza et al., 2017). At the same time, drawing on the CSPAP conceptualization of schools as social-ecological systems (Rudd et al., 2020; Bernhart et al., 2022; Chen et al., 2020), the HLP treats behavioral transfer (school-to-home/community) not as an individual responsibility but as an outcome of aligned learning opportunities across settings, thereby extending PE from a lesson-based curriculum into an ecosystemic pedagogy.

To operationalize this concept, the HLP draws upon the Comprehensive School Physical Activity Program (CSPAP) model, which frames schools as dynamic ecosystems integrating multiple learning contexts: structured lessons, physical activity during and beyond school hours, teacher reinforcement, and family-community support (Pardo et al., 2013; Kumala et al., 2019; Hadyansah et al., 2023).

Through this framework, the integration of physical literacy and fitness training serves as a pedagogical innovation that bridges the often-separated domains of physical competence and motivational learning. The approach enriches educational theory by offering a model that unites behavioral learning (habit formation), cognitive learning (knowledge and understanding), and affective learning (motivation and confidence), thereby expanding existing models of holistic education through the lens of embodied learning and self-regulated practice.

Empirical data from junior high schools in Tasikmalaya Regency, West Java, Indonesia, reveal that despite regular PE instruction, most students exhibit limited motivation for physical activity beyond school hours, coupled with sedentary habits such as gaming and consumption of high-sugar snacks. This situation not only reflects low physical literacy but also signals early patterns of lifestyle-related health risks, including obesity and metabolic disorders (Utami et al., 2018; Tejerina et al., 2018; Rocka et al., 2022). Global studies corroborate these findings, showing that over 80% of adolescents fail to meet the World Health Organization's physical activity recommendations (Chaput et al., 2020). Meanwhile, digital and school-based interventions focusing solely on fitness improvement often yield transient results, lacking the motivational and cognitive dimensions needed for sustainability (Weber et al., 2025; Fajrin et al., 2024).

The present study responds to this unresolved theoretical and methodological gap. Prior interventions frequently address physical literacy or fitness in isolation, neglecting their reciprocal and reinforcing relationship. Few have examined school-based models that simultaneously nurture cognitive-motivational engagement and measurable physical improvement within real-world learning constraints. This research introduces and tests the Healthy Lifestyle Program (HLP), a 12-week quasi-experimental intervention that integrates physical literacy instruction into PE lessons and extends it through school-home reinforcement strategies. Conceptually, this study advances contemporary educational theory by demonstrating how embodied and situated learning frameworks can strengthen behavioral transfer, thereby establishing a pedagogically grounded path toward sustainable adolescent health literacy and fitness development beyond traditional PE boundaries.

Materials and Methods

Participants

This study was conducted in several junior high schools in Tasikmalaya City, West Java, Indonesia. The community is predominantly of middle-to-upper socioeconomic status. Most parents work as civil servants, professionals, or entrepreneurs. They have high digital access, including smartphones and reliable internet. As a result, children spend

substantial screen time gaming and consuming digital media. Opportunities for outdoor play are limited due to dense academic schedules and tutoring.

Seventy-two Grade 7 students (N = 72; 19 males and 17 females per group), aged 13–14 years (mean = 13.6, SD = 0.4), met eligibility and consented to participate. Participants were allocated to the experimental or control group based on pre-existing intact classes to maintain normal school scheduling and instructional continuity. Although group equivalence was assessed at baseline, individual randomization was not performed; therefore, the study was classified as quasi-experimental rather than a randomized controlled trial.

Inclusion criteria: (1) age 13–14, (2) enrolled in junior high during the study, (3) parental/guardian consent, and (4) child's verbal assent. Exclusion criteria: (1) pre-existing physical or mental health conditions affecting participation, (2) involvement in a similar intervention in the past six months, (3) inability to provide informed assent or consent.

Research Design and Organization

This research employs a quasi-experimental design with pre- and post-tests to evaluate the impact of the Healthy Lifestyle Program on adolescents' physical literacy and fitness. The design allows for the comparison between an experimental group that participates in the intervention and a control group that does not, with both groups assessed at the beginning and end of the study. This approach provides a robust evaluation of the intervention's effectiveness while accounting for potential confounding variables.

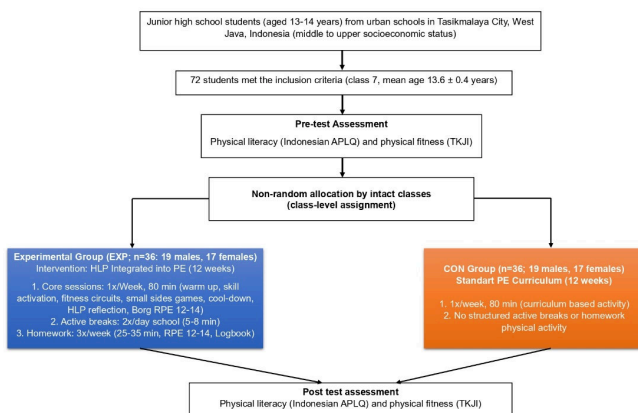


Fig. 1. Research Flows

Procedures

Experimental Group EXP

Participants in the experimental group received a 12-week Healthy Lifestyle Program (HLP) intervention integrated into regular Physical Education instruction, delivered once per week, with a duration of 2 × 40 minutes (80 minutes) per session, for a total of 12 instructional sessions. Each core HLP session was conducted at school facilities (field/gymnasium) and followed the time structure presented in Table 1, consisting of briefing and readiness (5 minutes), dynamic warm-up (10 minutes), motor skill activation (10 minutes), a

fitness circuit (20 minutes), small-sided games (20 minutes), a finisher (5 minutes), cool-down (5 minutes), and reflection with healthy lifestyle education (5 minutes), with themes mapped by weekly phases as shown in Table 2. The intended intensity for the core physical activity component was set at Borg RPE 12–14, representing moderate to “somewhat hard” intensity, so that the training load was sufficiently challenging while remaining controlled and safe for junior high school Physical Education contexts.

Table 1. Program Summary

Element	Description
Program duration	12 weeks.
Session duration	80 minutes (core HLP/Physical Education, 1× per week).
Time allocation per session	5 min briefing & readiness; 10 min dynamic warm-up; 10 min motor skill activation; 20 min fitness circuit; 20 min small-sided games; 5 min finisher; 5 min cool-down; 5 min reflection & healthy lifestyle education.
Borg RPE intensity	Target during the core physical activity: 12–14 (moderate to “somewhat hard”)
Overall physical activity frequency	Core HLP 1×/week (80 minutes) + classroom active breaks 2×/school day (5–8 minutes/break) + home-based physical activity homework 3×/week (25–35 minutes/session, target RPE 12–14). This design is intended to move students closer to the recommendation of 60 minutes/day of physical activity for children and adolescents.
Healthy lifestyle enrichment	Brief education of 1 theme/week during the reflection segment (5 minutes) and reinforcement of messages by homeroom teachers during active breaks, focusing on daily active habits, hydration, breakfast/snacking choices, sleep, and screen time management.
Target participants	Junior high school students (typically 12–14 years old, adjusted to the study sample).

Outside scheduled Physical Education sessions, the experimental group implemented classroom active breaks twice per school day (5–8 minutes per break), led by homeroom teachers using a standardized protocol to increase exposure to physical activity during school hours. In addition, participants were assigned structured physical activity homework three times per week, lasting 25–35 minutes per session and targeting Borg RPE 12–14 (Table 1 and Table 2), to help bring students closer to the recommendation of 60 minutes of daily physical activity for children and adolescents. The homework activities were designed and recommended by four Physical Education teachers who had been trained to use a standardized exercise menu to ensure consistency across classes, and each homework session was required to be recorded in a logbook (type of activity, duration, and RPE) as an indicator of adherence and as a means of monitoring intensity based on perceived exertion.

Table 2. Weekly Structure and Core Components of the Healthy Lifestyle Program (HLP)

Weeks	Core focus	School-based core components (80 min/session; high-level)	Target Borg RPE (during activity)	Healthy lifestyle literacy theme (core content)	Home-based component (dose summary only)
1–3	Adaptation and familiarization	Foundational movement skills + introductory circuit-based activity + participation-focused small-sided games	12–13 (within 12–14)	Daily active habits, hydration, and introduction to intensity self-monitoring using RPE	2–3×/week; 20–30 min/session; RPE 12–13
4–6	Progressive fitness development	Progressive circuit training (increased density) + small-sided games with higher engagement	12–14	Breakfast, healthier snack choices, and the energy–activity relationship	3×/week; 25–35 min/session; RPE 12–14
7–9	Integration and self-regulation	Combined aerobic intervals + functional circuit + decision-making games supporting physical literacy	13–14 (somewhat hard but controlled)	Sleep and recovery and their links to performance and motivation	3×/week; 25–35 min/session; RPE 13–14
10–12	Consolidation and independence	Mixed sessions (circuit + games) with stable intensity targets + reinforcement of sustainable routines	12–14 (stable)	Screen time management and development of a weekly physical activity plan	3×/week; 25–35 min/session; RPE 12–14

Note: The HLP was designed as a multicomponent intervention (school-based sessions + home-based physical activity). Adherence to the home-based component was monitored via student logbooks with parent/guardian verification, while full operational procedures (example activity packages, detailed session content, and monitoring templates) are provided in Supplementary Tables S1–S2 (Appendix/Supplement)

Facilitators and Training

The HLP intervention was delivered by four certified Physical Education teachers who completed an 8-hour program training session prior to implementation. The training covered the development of safe physical activity plans (including safety principles, posture, and injury prevention), techniques for monitoring training load using the Borg RPE (with emphasis on the 12–14 target as moderate to “somewhat hard” intensity), and reinforcement of the healthy lifestyle content to be delivered briefly and consistently during the reflection segment. A rating of 12–14 on the Borg RPE scale is commonly used to indicate moderate to somewhat hard exercise intensity.

The training also included procedures to standardize research data collection, including administration protocols for the physical literacy test (APLQ) and the physical fitness test (TKJI), to ensure consistent pretest–posttest implementation across facilitators. Because the HLP intervention included classroom active breaks, homeroom teachers served as implementers, carrying out a brief, standardized protocol rather than merely supervising. Homeroom teachers received a short orientation before the program began and were provided with ready-to-use materials (movement scripts, activity sequences, and safety guidance) to ensure consistent implementation across classes and documentation through a daily checklist.

Intensity control at the Borg RPE 12–14 target remained the responsibility of the Physical Education teachers during the core HLP sessions and the home-based physical activity homework, whereas classroom active breaks functioned as brief additional physical activity during school hours controlled through standardized procedures and adherence recording.

Monitoring instruments are provided in the Appendix/Supplement to support replication and transparent reporting of implementation fidelity.

Control Group (CON)

Students in the control group participated in conventional Physical Education lessons aligned with the school curriculum, with the same frequency and duration as the experimental group, namely one 80-minute session per week for 12 weeks. Instruction in the control group represented the school’s “natural activity” condition; therefore, no additional components were provided, such as structured classroom active breaks, and no programmed physical activity homework was assigned, as summarized in Table 3. Accordingly, any changes observed in the control group were expected to reflect the effects of routine instruction, while differences in change between groups could be interpreted as the impact of the HLP intervention.

Instrument

Physical Literacy

The Adolescent Physical Literacy Questionnaire (APLQ), translated into Bahasa Indonesia, will be used to assess physical literacy. It includes psychological and behavioral aspects, knowledge and awareness, competence, and physical activity levels. The questionnaire consists of 25 items, scored from 1 to 5, where 1 indicates low physical literacy and 5 indicates high physical literacy. The reliability of the APLQ has been established with a Cronbach’s alpha of 0.951, and the validity ranges from 0.680 to 0.790 (Mohammadzadeh et al., 2022). In this study, a 20% subsample of participants

Table 3. Summary of the Control Group Program

Element	Description
Physical Education instruction	1 session/week, 80 minutes in duration, with content following the school's standard curriculum.
Physical activity during school	No structured classroom active breaks (students follow the school's normal routine).
Home-based physical activity	No programmed physical activity homework (students follow their usual habits at home).
Healthy lifestyle component	No specific healthy lifestyle module provided by the researchers (only routine school education, if any).

Table 4. Format of Conventional Physical Education Sessions (Control Group)

Session segment	Duration	Activities	Teacher role	Student focus
Warm-up	10 minutes	Light jogging and general dynamic stretching, consistent with the school's usual Physical Education routine.	Leads the warm-up and ensures students' readiness.	Follows instructions and prepares the body.
Main activity	50 minutes	Standard curriculum-based Physical Education content (e.g., basic techniques of games/sports according to the school lesson plan).	Teaches the content, demonstrates skills, provides corrections, and manages the class.	Practices skills aligned with the lesson content and participates in learning activities.
Cool-down	20 minutes	Static stretching, light relaxation, and session closure.	Directs the cool-down and closes the lesson.	Recovers and follows the closing routine.

was independently rated by two Physical Education teachers to estimate inter-rater agreement for the Adolescent Physical Literacy Questionnaire (APLQ). Inter-rater reliability for the total APLQ physical literacy score demonstrated good consistency, with an ICC (two-way random, absolute agreement) of 0.82 (95% CI = 0.77–0.87), indicating adequate agreement between raters.

Physical Fitness (TKJI)

Physical fitness will be assessed using the Indonesian Physical Fitness Test (Tes Kesegaran Jasmani Indonesia; TKJI) for adolescents aged 13–15 years. The TKJI battery comprises a 50-meter sprint (speed), pull-ups (upper-body strength), sit-ups (abdominal strength and endurance), a vertical jump (explosive leg power), and a 1,000-meter middle-distance run for males and an 800-meter middle-distance run for females to assess cardiorespiratory endurance.

The validity and reliability of the TKJI are reported to be high, with a validity coefficient of 0.720 and a reliability of 0.920 (Dulanlebit, 2020). In this study, a 20% subsample of participants was independently assessed by two trained raters to estimate inter-rater agreement for the TKJI. Inter-rater reliability for the total TKJI score was excellent, with an ICC (two-way random, absolute agreement) of 0.88 (95% CI = 0.83–0.92), indicating high consistency between raters across all physical test items.

Statistical Analysis

Data were analyzed using SPSS. Prior to inferential testing, all datasets were screened for completeness and accuracy. Descriptive statistics were calculated for all physical literacy and physical fitness variables at pre-test and post-test. These statistics included means, standard deviations, minimum values, and maximum values. The content validity of the healthy lifestyle program was examined using Aiken's V coefficient based on expert judgments across predefined evaluation aspects. Aiken's V values exceeding the established threshold were interpreted as indicating acceptable content

validity. Internal consistency reliability of the validation instrument was assessed using Cronbach's alpha coefficient. Values above 0.70 were used as the reliability criterion.

The prerequisite analysis consisted of a normality test using the Shapiro-Wilk test and a homogeneity test using Levene's Test. Hypothesis testing used Multivariate Analysis of Variance (MANOVA). The effect size will be calculated using partial eta squared (η^2) following Cohen's (1988) criteria: small effect ($\eta^2 = 0.01$), medium effect ($\eta^2 = 0.06$), and large effect ($\eta^2 \geq 0.14$). Alternatively, Cohen's *f* may be used to interpret effect sizes: small ($f = 0.10$), medium ($f = 0.25$), and large ($f \geq 0.40$).

A post-hoc power consideration was conducted to evaluate whether the final sample size was sufficient to detect the observed effects. Given an alpha level of 0.05, a total sample size of 72, and the large observed effect sizes (partial $\eta^2 > 0.60$) obtained from the MANOVA and follow-up univariate analyses, the achieved statistical power can be considered to exceed the conventional threshold of 0.80 for both physical literacy and physical fitness outcomes, indicating adequate power to detect large intervention effects.

Results

This study used data that included validity (Aiken's V) and reliability (Cronbach's Alpha, Composite Reliability) results of the healthy lifestyle Program. Data were also obtained from pre-analysis tests and hypothesis tests based on the results of Physical Literacy tests (APLQ) and physical fitness tests (TKJI). The research involved two groups, namely, the experimental and control groups, each consisting of 36 students. Measurements were carried out in three stages: pre-test, post-test after 12 weeks. The results of the study are described as follows:

Validity and Reliability of the healthy lifestyle program

Content validity of the healthy lifestyle program was evaluated using Aiken's V based on ratings from four experts in Physical Education pedagogy and training across 20

Table 5. Healthy Lifestyle Program

No.	Rated Aspect	V	Decision
1	The program integrates Physical Education objectives in the Kurikulum Merdeka Phase D (junior high school, ages 13–14), with a focus on improving physical literacy and physical fitness.	1.00	Accepted
2	The program integrates specific movement skills through games/sports/activities to habituate physical activity and improve fitness.	0.88	Accepted
3	The program includes brief, relevant healthy lifestyle education to support physical literacy (e.g., the importance of physical activity, hydration, breakfast/snacking choices, sleep, and screen time management).	0.88	Accepted
4	The 80-minute session structure is appropriate for junior high school students, including briefing & readiness, dynamic warm-up, motor skill activation, a fitness circuit, small-sided games, a finisher, cool-down, and brief reflection/education.	0.88	Accepted
5	The fitness circuit design has clear duration and transitions, with gradual work–rest regulation to maintain exercise intensity at the target Borg RPE 12–14.	1.00	Accepted
6	The program progresses systematically from an adaptation phase (weeks 1–3), fitness capacity progression (weeks 4–6), integration of self-regulation (weeks 7–9), to consolidation and post-test preparation (weeks 10–12).	0.94	Accepted
7	The program implementation guide is adequate for junior high school Physical Education teachers, including activity instructions, group management, and intensity-monitoring procedures using Borg RPE.	0.94	Accepted
8	The program provides opportunities for students to observe demonstrations of movement skills and correct performance examples before the main practice and games.	1.00	Accepted
9	The program provides opportunities for brief question-and-answer activities and reflection at the end of the session segment and during activity transitions to strengthen students' understanding.	0.94	Accepted
10	The program uses equipment that is commonly available and easily adaptable in junior high schools (e.g., balls, cones, agility ladders, mats, ropes/markers, and field markers).	1.00	Accepted
11	The program addresses activity and equipment safety, including supervision procedures, safe zones, and intensity monitoring to remain within Borg RPE 12–14.	1.00	Accepted
12	The program has appeal and motivational potential to increase active participation among junior high school students through circuit variation, small-sided games, classroom active breaks, and home-based physical activity homework.	0.88	Accepted
13	The program integrates classroom active breaks led by homeroom teachers (2× per school day, 5–8 minutes) as a strategy to increase physical activity during school hours using a standardized protocol and daily checklist.	0.88	Accepted
14	The program provides structured home-based physical activity homework (3× per week, 25–35 minutes/session) with a target intensity of Borg RPE 12–14 and a standardized exercise menu to ensure consistent training exposure.	0.88	Accepted
15	The program establishes mechanisms to monitor adherence and training load through student logbooks (activity type, duration, RPE) and parental verification, accompanied by periodic evaluation by Physical Education teachers.	0.88	Accepted
16	The program sets safety standards for home-based physical activity, including warm-up–cool-down instructions, selection of a safe area, and movement modifications for students reporting complaints to minimize injury risk.	1.00	Accepted
17	The program provides procedures for adjusting training load (progression/regression) based on RPE, enabling students to increase or decrease intensity in a guided manner without changing session objectives.	0.94	Accepted
18	The program ensures cross-teacher implementation coherence through an intervention module and uniform reporting formats (session structure, RPE indicators, active-break checklist, and homework logbooks), so implementation is consistent across classes and readily replicable.	0.88	Accepted
19	The program establishes procedures for handling participants unable to attend sessions (e.g., illness or authorized absence), including make-up/compensatory activity opportunities and adherence-recording rules, to minimize loss of intervention dose.	1.00	Accepted
20	The equipment used in the program is simple, readily obtainable, and accessible both at school and at participants' homes, supporting practical implementation.	1.00	Accepted
	Mean	0.94	Accepted

*All indicators exceeded 0.80 (acceptance criterion)

indicators. The mean Aiken's V value was 0.94 (range: 0.90–1.00), exceeding the minimum threshold of 0.80. The internal consistency reliability of the validation instrument reached Cronbach's $\alpha = 0.713$, indicating acceptable reliability. Detailed validation and reliability results are provided in Tables 5 and 6.

Reliability Test Results

Table 6. Reliability Test Results of the Healthy Lifestyle Realization Program

Cronbach's Alpha	N of Items
0,713	20

Descriptive Results

Table 7. Descriptive Statistics of Physical Literacy and Physical Fitness

Variable	Group	Pretest, mean (SD)	Posttest, mean (SD)
Physical Literacy	Experimental	72.25 (10.898)	97.00 (10.190)
	Control	73.56 (10.937)	73.11 (10.725)
Physical Fitness	Experimental	11.86 (2.206)	18.81 (1.117)
	Control	12.50 (2.432)	12.58 (2.347)

* Values are presented as mean (SD)

Based on the descriptive statistics in Table 7, the pretest scores for physical literacy and physical fitness were broadly comparable between the experimental group (n = 36) and the control group (n = 36), indicating good baseline equivalence (pretest mean differences < 2 points). Following the 12-week intervention, the experimental group showed substantial improvements at posttest (physical literacy: +24.75 points; physical fitness: +6.95 points), accompanied by reduced standard deviations, suggesting greater score consistency across participants. In contrast, the control group remained stable or showed a slight decline (physical literacy: -0.45 points; physical fitness: +0.08 points), indicating minimal natural change in the absence of the intervention.

Table 8. Descriptive Statistics of Score Changes

Variable	Group	Mean	SD
Gain Physical Literacy	Experimental	24.75	14.516
	Control	-0.44	2.184
Gain Physical Fitness	Experimental	6.94	2.506
	Control	0.08	0.604

* Score changes represent differences between posttest and pretest scores

The descriptive change scores in Table 8 show a dramatic improvement in the experimental group, with gains in physical literacy (M = 24.75, SD = 14.516) and physical fitness (M = 6.94, SD = 2.506), which far exceed the control group, where changes were minimal or slightly negative (physical literacy gain = -0.44; physical fitness gain = 0.08). The larger standard deviation for physical literacy gains in the experimental group indicates greater dispersion of individual responses around the mean, suggesting that participants benefited to varying degrees, whereas the smaller dispersion in physical fitness gains implies a more uniform improvement across students.

Normality Test Results

Table 9. Test of Normality

Variable	Group	Kolmogorov-Smirnov (Sig.)	Shapiro-Wilk (Sig.)
Gain Physical Literacy	Experimental	0.200	0.542
	Control	0.177	0.088
Gain Physical Fitness	Experimental	0.063	0.095
	Control	0.183	0.371

The normality tests reported in Table 9 (Kolmogorov-Smirnov and Shapiro-Wilk) indicate that all gain-score data in both groups were normally distributed (p > 0.05)

Homogeneity of Variance Test Results

Table 10. Levene's Test of Homogeneity of Variance

Variable	F	df1	df2	Sig.
Gain Physical Literacy	40.892	1	70	0.547
Gain Physical Fitness	56.432	1	70	0.443

The variance homogeneity test reported in Table 10 (Levene's test) shows that between-group variances were homogeneous for both variables (p > 0.05). Therefore, these results support that the dataset met key assumptions required to proceed with MANOVA.

Hypothesis Test Results

Table 11. Multivariate Analysis of Variance Results

Test	Value	F	Hypothesis df	Error df	Sig.
Wilks' Lambda	0.180	1.572	2.000	69.000	0.000

The multivariate MANOVA results in Table 11 indicate that the Healthy Lifestyle Program produced a statistically significant simultaneous effect on changes in physical literacy and physical fitness (Wilks' Lambda = 0.180; p < 0.001). In MANOVA, Wilks' Lambda tests whether groups differ on a combined (linear) pattern of multiple dependent variables, and smaller Lambda values indicate that a greater proportion of variance is explained by group differences. Therefore, the observed Wilks' Lambda value, together with p < 0.001, supports the conclusion that the program significantly influenced the two outcomes jointly. However, it is important to note that the observed effect size may be inflated due to the quasi-experimental design, which lacks randomization and could lead to potential confounding factors affecting the results.

Follow-up univariate analyses in Table 12 confirm that the Healthy Lifestyle Program (HLP) had a statistically significant effect on gains in physical literacy, F(1,70) = 106.051, p < 0.001, partial η² = 0.602, and on gains in physical fitness, F(1,70) = 254.963, p < 0.001, partial η² = 0.785. Using common interpretive conventions for partial eta squared (with η² ≥ 0.14 typically considered a large effect), both values indicate a large-to-very-large effect size, implying that the program accounted for a substantial proportion of variance in both outcomes. Consequently, the magnitude of partial η² for both variables supports the interpretation that the HLP produced strong improvements in students' physical literacy and physical fitness. However, it should be noted that the absence of cluster-level or school-level controls may affect the validity of the findings, as unaccounted-for variability at these levels could influence the results. Therefore, caution should be exercised when generalizing the findings to other settings.

Discussion

This study tested the primary hypothesis that a 12-week integrated Healthy Lifestyle Program (HLP) would improve physical literacy and physical fitness among junior high school students aged 13-14 years. Substantial improvements were observed in the experimental group relative to the

Table 12. Tests of Between-Subjects Effects

Dependent Variable	Source	df	F	Sig.	Partial η^2	Interpretation
Gain Physical Literacy	Group	1	106.051	0.000	0.602	Large effect
Gain Physical Fitness	Group	1	254.963	0.000	0.785	Large effect

control group, while baseline equivalence between groups was maintained at pretest. Accordingly, the observed posttest differences are most plausibly associated with participation in the HLP intervention. The experimental group demonstrated marked gains in both physical literacy and TKJI-based physical fitness, whereas the control group remained largely stable across the study period. These findings are supported by large effect sizes for physical literacy and very large effect sizes for physical fitness. Although the magnitude of these effects exceeds those typically reported in many school-based Physical Education interventions, including large-scale syntheses and long-term school programs (e.g., García-Hermoso et al., 2020; Meyer et al., 2014; Westcott, 2015; Eather et al., 2016), this difference may reflect the multicomponent structure of the HLP, its contextual specificity, and the quasi-experimental design, which may contribute to inflated effect estimates. Therefore, the effect sizes should be interpreted as strong but provisional indicators of program impact rather than definitive benchmarks for causal inference.

These findings underscore the relevance of the present results, as the HLP addresses deficits in physical literacy and physical fitness among urban Indonesian adolescents, including students in Tasikmalaya Regency, West Java, Indonesia, where daily screen time frequently exceeds two hours. The observed effects appear to emerge through a set of interrelated pedagogical mechanisms rather than from isolated program components. These mechanisms include the integration of brief, developmentally appropriate educational content (e.g., screen time management, nutrition, and sleep) with structured movement experiences, fostering positive interdependence between knowledge acquisition, motivation, and behavioral engagement. This approach is consistent with contemporary physical literacy frameworks, which conceptualize physical literacy as an educational outcome arising from the interaction of cognitive, affective, and behavioral domains (Yli-Piipari et al., 2021; Lemes et al., 2024). In addition, the combination of circuit-based activities and small-sided games delivered at a moderate-to-somewhat-hard intensity (Borg RPE 12–14), together with classroom active breaks and home-based physical activity assignments, is likely to support reductions in sedentary behavior and promote behavioral transfer beyond the Physical Education lesson (Mukhlis et al., 2022; Dong et al., 2021; Priyantono et al., 2022; Qu et al., 2025). The systematic progression from adaptation to consolidation, reinforced through logbooks and parental verification of participation, responds to critiques of fragmented school-based interventions (Chriqui et al., 2021) and carries preventive implications for obesity and metabolic disorders in adolescence (Guthold et al., 2020). At a broader level, the HLP represents a low-cost and contextually adaptable intervention model with potential relevance for low- and middle-income countries, where a large proportion of adolescents do not meet WHO physical activity guidelines (Chaput et al., 2020), thereby aligning with Sustainable Development Goal target 3.4.

From a practical standpoint, the HLP can be readily integrated into Kurikulum Merdeka Phase D. It relies on simple equipment (e.g., balls, cones, mats) and structured teacher guidance, which supports scale-up in public schools with limited resources. This program functions as a compensatory intervention for urban sedentary lifestyles and supports national adolescent health policies. Globally, the model may be adapted to primary–secondary education systems in regions with high adolescent obesity prevalence, such as Southeast Asia and Latin America, where community-based interventions have reduced long-term cardiovascular risk (Morales-Juárez, 2025). There is also potential to integrate the model into digital platforms for post-pandemic schools that rely on hybrid learning.

At the same time, the quasi-experimental Design implies a nontrivial risk that the estimated effects are inflated because participants were not individually randomized and clustering at the school/class level could not be fully controlled. In practice, unmeasured differences between groups (e.g., teacher emphasis, peer norms, or baseline motivation) and limited cluster control (i.e., a single-school context) may bias posttest contrasts upward; consequently, the true program impact may be more modest than observed, and the reported effects could be overstated by approximately 10–20%. For this reason, the effect sizes should be interpreted as strong but provisional estimates, and any generalisation beyond comparable junior high school settings should be made cautiously.

Nevertheless, limitations include the relatively short duration of 12 weeks, the restricted sample of 72 students from Tasikmalaya Regency, the quasi-experimental design's vulnerability to bias, and reliance on self-report measures. In addition, the small sample and single-site setting constrain external validity, meaning the results may not transfer to schools with different staffing, facilities, or student sociodemographic profiles. In light of these limitations, future research directions include a randomized controlled trial (RCT) with school-level randomization and 6–12-month longitudinal follow-up, a multi-center study involving more than 200 students across rural urban contexts, objective validation using accelerometers, moderator analyses such as gender and BMI, economic evaluation of scalability, comparisons with other models such as TGfU or TPSR, and qualitative approaches examining student, teacher, and parent experiences, with particular emphasis on replication across multiple schools to strengthen cluster control and to test whether the observed effects persist under routine implementation conditions, alongside expansion to international contexts to validate effectiveness across different national income levels.

Conclusion

This study demonstrates that the Healthy Lifestyle Program (HLP) can be implemented as an integrated pedagogical approach to support the development of physical literacy and physical fitness among junior high school students. The 12-

week intervention was associated with significant effects in both domains. This indicates that physical literacy learning and fitness improvement can be addressed within a single, coherent instructional framework. These findings have practical implications for educational settings with limited Physical Education instructional time and facilities. The program can be delivered within regular Kurikulum Merdeka Physical Education lessons without requiring specialized equipment or additional infrastructure. The observed improvement in physical literacy suggests the relevance of HLP as a preventive approach to sedentary lifestyles and long-term health risks in early adolescence. In light of limitations related to intervention duration and sample characteristics, the results support using HLP as an instructional approach aligned with physical literacy objectives and the integrated promotion of healthy lifestyles in junior high school Physical Education. These efforts are broadly consistent with public health goals aimed at reducing the risk of noncommunicable diseases.

Ethics Approval

This study received ethical approval from the Siliwangi University Ethics Committee (approval number: 0529/C3/DT.02.00/2025, dated February 8, 2025) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians prior to participation, and verbal assent was obtained from all participating students before data collection and intervention activities commenced.

Informed Consent

Prior to participation, students and their parents or legal guardians received comprehensive written and verbal information regarding the study objectives, procedures, duration, potential risks and benefits, the voluntary nature of participation, and the right to withdraw at any time without negative consequences. Written informed consent was obtained from parents or guardians, and student assent was obtained before participation.

Participant confidentiality was ensured through data anonymization. All personal identifiers were coded, and datasets were stored in password-protected files accessible only to the research team.

Participant safety was ensured through:

- (1) baseline health screening to identify contraindications to moderate physical activity,
- (2) supervision of all school-based sessions by certified Physical Education teachers,
- (3) monitoring of exercise intensity using the Borg Rating of Perceived Exertion (RPE 12–14), and
- (4) continuous observation for any adverse events throughout the intervention period.

No adverse events related to participation in the Healthy Lifestyle Program were reported during the study.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AI Transparency Statement

In preparing this manuscript, the authors used Perplexity AI to support sentence structuring and language refinement. All content was critically reviewed, edited, and verified by the authors, who take full responsibility for the accuracy, originality, and integrity of the manuscript.

Acknowledgements

The authors sincerely thank Siliwangi University for providing research facilities and institutional support. The authors also express their gratitude to the school principals, Physical Education teachers, and students from junior high schools in Tasikmalaya City, Indonesia, for their cooperation and valuable participation in this study.

Funding Statement

This study was self-funded and received no external funding.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

References

- Mehtälä, A., Villberg, J., Blomqvist, M., Huotari, P., Jaakkola, T., Koski, P., ... & Kokko, S. (2020). Individual- and environmental-related correlates of moderate-to-vigorous physical activity in 11-, 13-, and 15-year-old Finnish children. *Plos One*, 15(6), e0234686. <https://doi.org/10.1371/journal.pone.0234686>
- Fierro-Suero, S., Ozcorta, E., & Buñuel, P. (2022). Students' motivational and emotional experiences in physical education across profiles of extracurricular physical activity: The influence in the intention to be active. *International Journal of Environmental Research and Public Health*, 19(15), 9539. <https://doi.org/10.3390/ijerph19159539>
- Estevan, I., García-Massó, X., Menescardi, C., Ortega-Benavent, N., Montalt-García, S., Romero-Martínez, J., ... & Molina-García, J. (2023). A classroom-based intervention to promote physical literacy in children: ALPHYL study protocol. *Behavioral Sciences*, 13(7), 609. <https://doi.org/10.3390/bs13070609>
- Yli-Piipari, S., Gråsten, A., Huhtiniemi, M., Salin, K., Seppälä, S., Hakonen, H., & Jaakkola, T. (2021). Predictive strength of physical education-centered physical literacy indicators on physical activity. *Journal of Teaching in Physical Education*, 40(2), 303–311. <https://doi.org/10.1123/jtpe.2019-0144>
- Caldwell, H., Cristofaro, N., Cairney, J., Bray, S., MacDonald, M., & Timmons, B. (2020). Physical literacy, physical activity, and health indicators in school-age children. *International Journal of Environmental Research and Public Health*, 17(15), 5367. <https://doi.org/10.3390/ijerph17155367>
- Castillo, I., Molina-García, J., Estevan, I., Queral, A., & Álvarez, O. (2020). Transformational teaching in physical education and students' leisure-time physical activity: The mediating role of learning climate, passion, and self-determined motivation. *International Journal of Environmental Research and Public Health*, 17(13), 4844. <https://doi.org/10.3390/ijerph17134844>

- Nguyen, A., Powers, J., Braick, P., Foss, J., & Morse, D. (2025). Community Health Worker Adherence to Self-Determination Theory in the Women's Initiative Supporting Health Intervention-Based Study. *Journal of Correctional Health Care*, 31(4), 262-273. <https://doi.org/10.1089/jchc.25.03.0018>
- Lima, A., Sorroche, J., Tagiku, A., & Neto, J. (2024). Digital pedagogy: experiential learning theory improves mathematics learners' engagement and learning outcomes in optical physics course. *Physics Education*, 59(5), 055007. <https://doi.org/10.1088/1361-6552/ad5f6d>
- Ockerman, L. S., & Bagui, S. (2024). Critical Reflection Sessions: Teacher's Perspectives During Professional Development. *International Journal of Changes in Education*. <https://doi.org/10.47852/bonviewIJCE42023792>
- Rudd, J., Crotti, M., Davies, K., O'Callaghan, L., Bardid, F., Utesch, T., ... & Foweather, L. (2020). Skill Acquisition Methods Fostering Physical Literacy in Early-Physical Education (SAMPLE-PE): Rationale and Study Protocol for a Cluster Randomized Controlled Trial in 5-6-Year-Old Children From Deprived Areas of North West England. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.01228>
- Bernhart, J., Wilcox, S., McKeever, B., Ehlers, D., & O'Neill, J. (2022). A Self-Determination Theory Application to Physical Activity in Charity Sports Events. *American Journal of Lifestyle Medicine*, 19(2), 242-252. <https://doi.org/10.1177/15598276221077204>
- Chen, R., Wang, L., Wang, B., & Zhou, Y. (2020). Motivational climate, need satisfaction, self-determined motivation, and physical activity of students in secondary school physical education in China. *BMC Public Health*, 20(1). <https://doi.org/10.1186/s12889-020-09750-x>
- Lev-Arey, D., Gutman, T., & Levental, O. (2024). Empowering Movement: Enhancing Young Adults' Physical Activity through Self-Determination Theory and Acceptance and Commitment Therapy-Based Intervention. *Behavioral Sciences*, 14(2), 130. <https://doi.org/10.3390/bs14020130>
- Lee, Y. L., Murillo, A., Gomes, C., Faktor, K., Brian, R., Cate, O. T., O'Sullivan, P., & Vu, L. (2025). What Motivates General Surgery Residents to Request Entrustable Professional Activity Assessments? A Qualitative Study. *In Review*. <https://doi.org/10.21203/rs.3.rs-6946204/v1>
- Mendoza, J.A., Baker, K.S., Moreno, M.A., Whitlock, K.B., Abbey-Lambertz, M., Waite, A., ... & Chow, E.J. (2017). A Fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: A pilot study. *Pediatric Blood & Cancer*, 64(12). <https://doi.org/10.1002/pbc.26660>
- Pardo, B., Bengoechea, E., Lanaspá, E., Bush, P., Casterad, J., Clemente, J., ... & García-González, L. (2013). Promising school-based strategies and intervention guidelines to increase physical activity of adolescents. *Health Education Research*, 28(3), 523-538. <https://doi.org/10.1093/her/cyt040>
- Kumala, A.M., Margawati, A., & Rahadiyanti, A. (2019). Hubungan antara durasi penggunaan alat elektronik (gadget), aktivitas fisik dan pola makan dengan status gizi pada remaja usia 13-15 tahun. *Journal of Nutrition College*, 8(2), 73. <https://doi.org/10.14710/jnc.v8i2.23816>
- Hadyansah, D., Dimiyati, D., & Ardiyanto Hermawan, H. (2025). El efecto del programa integral de actividad física escolar (CSPAP) en la alfabetización física de los alumnos. *Retos*, 70, 95-105. <https://doi.org/10.47197/retos.v70.110310>
- Utami, N.P., Purba, M.B., & Huriyati, E. (2018). Exposure of screen time in relationship with obesity in junior high school adolescence in Yogyakarta. *Jurnal Dunia Gizi*, 1(2), 71. <https://doi.org/10.33085/jdg.v1i2.3419>
- Tejerina, L., Perez-Cuevas, R., Adderley, B., Delevaux, C., Braithwaite, N., Kuster, R., Osorio, I., & García, G. (2018). Associated Factors of Healthy Lifestyle in the Bahamas. *Inter-American Development Bank*. <https://doi.org/10.18235/0009376>
- Rocka, A., Jasielska, F., Madras, D., Krawiec, P., & Pac-Kozuchowska, E. (2022). The impact of digital screen time on dietary habits and physical activity in children and adolescents. *Nutrients*, 14(14), 2985. <https://doi.org/10.3390/nu14142985>
- Chaput, J., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., ... & Katzmarzyk, P. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5-17 years: Summary of the evidence. *International Journal of Behavioral Nutrition and Physical Activity*, 17(1). <https://doi.org/10.1186/s12966-020-01037-z>
- Weber, R.-M., Anand, C., Koeder, C., Husain, S., Schoch, N., Kettler, C., Buyken, A., & Englert, H. (2025). Healthy lifestyle changes can improve quality of life: The Healthy Lifestyle Community Program (cohort 2; HLCP-2). *Journal of Public Health (Berl.)*, 67(4), 350. <https://doi.org/10.1007/s10389-025-02409-0>
- Mohammadzadeh, M., Abadi, D.H. S., Bagherzadeh, F., & Kazemnejad, A. (2022). Design and psychometrics evaluation of adolescent physical literacy questionnaire (APLQ). *Sport Sci Health*, 18(2), 394-405. <https://doi.org/10.1007/s11332-021-00818-8>
- Dulanlebit, J. (2020). Survei tingkat kebugaran jasmani atlet Karate Dojo Redland Halong usia 13-15 tahun dalam persiapan Kejurda Redland li 2019 di Ambon. *MANGGUREBE: Journal Physical Education, Health and Recreation*, 1(1), 1-10. <https://garuda.kemdiktisaintek.go.id/documents/detail/3607274>
- García-Hermoso, A., Alonso-Martínez, A. M., Ramírez-Vélez, R., Pérez-Sousa, M. Á., Ramírez-Campillo, R., & Izquierdo, M. (2020). Association of Physical Education With Improvement of Health-Related Physical Fitness Outcomes and Fundamental Motor Skills Among Youths: A Systematic Review and Meta-analysis. *JAMA Pediatrics*, 174(6), e200223. <https://doi.org/10.1001/jamapediatrics.2020.0223>
- Fajrin, A. N., Nopembri, S., & Hastuti, T. A. (2025). Physical literacy: Physical literacy knowledge and its relationship to physical fitness of senior high school students. *Retos*, 63, 1101-1112. <https://doi.org/10.47197/retos.v63.111244>
- Meyer, U., Schindler, C., Zahner, L., Ernst, D., Hebestreit, H., Mechelen, W., ... & Kriemler, S. (2014). Long-term effect of a school-based physical activity program (KISS) on fitness and adiposity in children: A cluster-randomized controlled trial. *Plos One*, 9(2), e87929. <https://doi.org/10.1371/journal.pone.0087929>
- Eather, N., Morgan, P., & Lubans, D. (2016). Effects of exercise on mental health outcomes in adolescents: Findings from the CrossFit™ teens randomized controlled trial. *Psychology of Sport and Exercise*, 26, 14-23. <https://doi.org/10.1016/j.psychsport.2016.05.008>
- Khory, F. (2025). Peningkatan pemahaman physical literacy bagi guru PJOK. *Laksana Olahraga*, 3(02), 69-79. <https://doi.org/10.26740/laksanaolahraga.v3i02.68144>
- Wahyudi, I., Simanjuntak, V., Bafadal, M., & Wardhani, R. (2023). Penerapan pola hidup sehat dalam pendidikan

- jasmani untuk meningkatkan karakter disiplin pada siswa Mas Khulafaur Rasyidin. *Riyadhoh Jurnal Pendidikan Olahraga*, 6(1), 81. <https://doi.org/10.31602/rjpo.v6i1.9956>
- Lemes, V., Sehn, A., Reuter, C., Burns, R., Gaya, A., Gaya, A., ... & Brand, C. (2024). Associations of sleep time, quality of life, and obesity indicators on physical literacy components: A structural equation model. *BMC Pediatrics*, 24(1). <https://doi.org/10.1186/s12887-024-04609-1>
- Mukhlis, N., Kurniawan, A., & Kurniawan, R. (2022). Pengembangan media kebugaran jasmani unsur kekuatan berbasis multimedia interaktif. *Sport Science and Health*, 2(11), 566-581. <https://doi.org/10.17977/um062v2i112020p566-581>
- Dong, X., Ding, L., Zhang, R., Ding, M., Wang, B., & Yi, X. (2021). Physical activity, screen-based sedentary behavior, and physical fitness in Chinese adolescents: A cross-sectional study. *Frontiers in Pediatrics*, 9. <https://doi.org/10.3389/fped.2021.722079>
- Priyantono, E., Aswara, A., & Rosidi, S. (2022). Partisipasi reseptif, persepsi manfaat, aksesibilitas fasilitas dan partisipasi aktif olahraga siswa SD di Indonesia. *Multilateral Jurnal Pendidikan Jasmani Dan Olahraga*, 21(3), 268. <https://doi.org/10.20527/multilateral.v21i3.14564>
- Qu, Q., Li, H., Meng, J., Liu, Yang, Gao, J., Yu, N., Liu, X., Meng, W., Wang, X., Li, Q., Feng, X., Liu, Yafei, Sun, Z., Shen, J., Qian, M., Lu, Y., Meng, Y., Tu, M., Jiang, J., ... Wen, D. (2025). Relationship between comprehensive healthy lifestyle score and multimorbidity among children and adolescents. *In Review*. <https://doi.org/10.21203/rs.3.rs-6659438/v1>
- Chriqui, J., Leider, J., Piekarz-Porter, E., Lin, W., Turner, L., Michael, S., ... & Perna, F. (2021). "Waiving" goodbye to PE: State law and school exemption and substitution practices in the United States. *Translational Journal of the American College of Sports Medicine*, 6(2). <https://doi.org/10.1249/tjx.0000000000000161>
- Guthold, R., Stevens, G., Riley, L., & Bull, F. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *The Lancet Child & Adolescent Health*, 4(1), 23-35. [https://doi.org/10.1016/s2352-4642\(19\)30323-2](https://doi.org/10.1016/s2352-4642(19)30323-2)
- Morales-Juárez, A. (2025). School-based interventions to prevent overweight in Latin America: A scoping review and policy analysis. *Nutrients*, 17(21), 3435. <https://doi.org/10.3390/nu17213435>
- Westcott, W. (2015). Physiological effects of the BOKS before-school physical activity program for preadolescent youth. *Journal of Exercise Sports & Orthopedics*, 2(2), 01-07. <https://doi.org/10.15226/2374-6904/2/2/00129>

Програма здорового способу життя для підвищення фізичної грамотності та фізичної підготовленості учнів молодшого підліткового віку: квазіекспериментальне дослідження

Невітанінґрум^{1ABCDE}, Пепеп Мохамад Сяфеї^{1ADE}, Гумілар Мультя^{1ADE}, Тріснар Аді Прабово^{2CD}, Октавіаріні Ях'я Рахмдханті^{3CD}, Путу Деаніті Ай Деста Сур'яні^{4CD}

¹ Університет Сілівангі;

² Університет Мухаммадія Бребес;

³ Університет Сінгапербанґса Караванг;

⁴ Державний університет Джок'якарти

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 12 с., 12 табл., 1 рис., 40 джерел.

Мета дослідження. Метою цього квазіекспериментального дослідження було оцінити ефективність Програми здорового способу життя (Healthy Lifestyle Program, HLP), інтегрованої в регулярні заняття з фізичного виховання, щодо підвищення рівня фізичної грамотності та фізичної підготовленості учнів молодшого підліткового віку (13–14 років), а також протидії сидячій поведінці, пов'язаній із надмірним екранним часом та обмеженими можливостями для активного відпочинку на відкритому повітрі.

Матеріали і методи. У дослідженні взяли участь 72 учні (середній вік = 13,6 ± 0,4 року; 19 хлопців і 17 дівчат у кожній групі), яких було розподілено на експериментальну (EXP; n = 36) та контрольну (CON; n = 36) групи з використанням нерендомізованого розподілу на основі цілісних класів, що відповідає квазіекспериментальному дизайну. Учасники експериментальної групи брали участь у програмі HLP, яка включала щотижневі 80-хвилинні заняття з елементами розминки, активізації рухових навичок, фітнес-циркулярів, ігор у малих групах, класних активних перерв та домашніх завдань з фізичної активності з цільовою інтенсивністю Borg RPE 12–14, доповнених щотижневими освітніми модулями зі здорового способу життя. Контрольна група навчалася за стандартною програмою з фізичного виховання. Фізичну грамотність оцінювали за допомогою індонезійської адаптації опитувальника Adolescent Physical Literacy Questionnaire (APLQ; Cronbach's $\alpha = 0,951$), а фізичну підготовленість — за допомогою Індонезійського тесту фізичної підготовленості (TKJI; валідність = 0,720; надійність = 0,920). Міжккзаменаторська надійність була високою (APLQ ICC = 0,82; TKJI ICC

= 0,88). Змістову валідність програми підтверджено за допомогою коефіцієнта Aiken's V (0,94). Статистичний аналіз включав описову статистику, критерій Шапіро-Вілکا для перевірки нормальності розподілу, критерій Левена для перевірки однорідності дисперсій та багатовимірний дисперсійний аналіз (MANOVA) з обчисленням часткових η^2 .

Результати. Початкові показники в обох групах були зіставними. В експериментальній групі виявлено суттєве зростання рівня фізичної грамотності (приріст = $24,75 \pm 14,52$) та фізичної підготовленості (приріст = $6,94 \pm 2,51$), тоді як у контрольній групі зміни були мінімальними (фізична грамотність: $-0,44 \pm 2,18$; фізична підготовленість: $0,08 \pm 0,60$). Результати MANOVA засвідчили статистично значущий багатовимірний ефект (Wilks' $\Lambda = 0,180$; $p < 0,001$) із великими розмірами ефекту як для фізичної грамотності ($\eta^2 = 0,602$), так і для фізичної підготовленості ($\eta^2 = 0,785$). Усі статистичні припущення було дотримано.

Висновки. Програма здорового способу життя (HLP) забезпечила статистично значуще підвищення рівня фізичної грамотності та фізичної підготовленості учнів молодшого підліткового віку. Отримані результати підтверджують доцільність інтеграції освітньо обґрунтованих, багатокomпонентних програм здорового способу життя в шкільні навчальні плани, зокрема в межах Kurikulum Merdeka, як ефективного засобу протидії сидячій поведінці з використанням доступних та контекстно релевантних ресурсів. Подальші дослідження мають бути спрямовані на вивчення довготриваліших інтервенцій та ширшого спектра соціально-економічних контекстів.

Ключові слова: програма здорового способу життя, фізична грамотність, фізична підготовленість, молодший підлітковий вік.

Information about the Authors:

Nevitaningrum: nevitaningrum@unsil.ac.id, <https://orcid.org/0009-0004-5953-3714>; Department of Physical Education, Universitas Siliwangi, Jl. Siliwangi No. 24, Kahuripan, Tawang, Tasikmalaya 46115, Jawa Barat, Indonesia.

Syafei Pepap Mochamad: pepap.mochamadsyafei@unsil.ac.id, <https://orcid.org/0009-0006-4963-1884>, Department of Physical Education, Universitas Siliwangi, Jl. Siliwangi No. 24, Kahuripan, Tawang, Tasikmalaya 46115, Jawa Barat, Indonesia.

Mulya Gumilar: gumilarmulya@unsil.ac.id, <https://orcid.org/0000-0002-8953-1873>; Department of Physical Education, Universitas Siliwangi, Jl. Siliwangi No. 24, Kahuripan, Tawang, Tasikmalaya 46115, Jawa Barat, Indonesia.

Prabowo Trisnar Adi: trisnar.prabowo@ums.ac.id, <https://orcid.org/0000-0001-6977-0503>; Study Program of Physical Education, Muhammadiyah Brebes University, Jl. Pangeran Diponegoro Grengseng No.184, Grengseng, Taraban, Kec. Paguyangan, Kabupaten Brebes, Jawa Tengah 52276, Indonesia.

Rahmadhanty Oktaviarini Yahya: oktaviarini.yahya@fkip.unsika.ac.id, <https://orcid.org/0009-0008-3071-7199>, Department of Physical Education, Health, and Recreation, Faculty of Teacher Training and Education, Singaperbangsa Karawang University, Jl. HS. Ronggowaluyo, Telukjambe Timur, Karawang, West Java, Indonesia.

Suryani Putu Deanita I Desta: deanitaidesta98@gmail.com, <https://orcid.org/0009-0007-1601-190X>, Departement of Biology, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Jl. Colombo No. 1, Karang Malang, Caturtunggal, Depok District, Sleman Regency, Special Region of Yogyakarta 55281, Indonesia.

Cite this article as: Nevitaningrum, N., Syafei, P. M., Mulya, G., Prabowo, T. A., Rahmadhanty, O. Y., & Suryani, P. D. I. D. (2026). Healthy Lifestyle Program to Improve physical literacy and Physical Fitness of Junior High School Students: A Quasi-Experimental Approach. *Journal of Learning Theory and Methodology*, 7(1), 25-36. <https://doi.org/10.17309/jltm.2026.7.1.02>

Received: 04.01.2026. Accepted: 21.01.2026. Published: 30.04.2026

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>)



Beyond Course Averages: A Generalized Bayesian Hierarchical Framework for Course-Level Learning Evaluation

Vicente E. Montano^{1ABCD} and Archie G. Reyes^{1ABCD}

¹University of Mindanao

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.1.04

Abstract

Background. Course-level learning assessment in higher education is commonly based on comparisons of average performance indicators, implicitly assuming independence across courses and equal reliability of estimates. When enrollments are small and uneven, such approaches produce statistically unstable estimates and exaggerate extreme values, leading to potentially misleading interpretations.

Objectives. This study aims to develop a generalizable methodological framework for applying Bayesian hierarchical modeling (BHM) to course-level learning assessment, explicitly accounting for sampling uncertainty and unequal group sizes.

Materials and Methods. A Bayesian hierarchical model was specified in which student learning outcomes were modeled at the individual level while accounting for course membership. The model decomposes total variance into within-course and between-course components and estimates course-level effects using posterior distributions. Partial pooling was applied to stabilize estimates for courses with small enrollments. An empirical illustration was conducted using anonymized data from 279 students across 22 courses.

Results. Naïve comparisons based on course averages were found to systematically exaggerate extreme outcomes under small sample conditions, resulting in unstable and potentially misleading conclusions. The application of Bayesian hierarchical modeling substantially reduced artificial extremity while preserving statistically supported between-course differences. After pooling, most course effects were not distinguishable from the program average, while a limited number of courses showed consistent deviations.

Conclusions. Bayesian hierarchical modeling provides a statistically robust alternative to descriptive aggregation and course ranking. By incorporating uncertainty and stabilizing estimates, it enables more reliable interpretation of course-level performance and supports targeted, evidence-based academic evaluation.

Keywords: bayesian hierarchical modeling, multilevel analysis, course-level assessment, small sample instability, educational measurement.

Introduction

Performance indicators are instrumental in aligning with a program's expectations, thereby facilitating course delivery strategies and assessment procedures (Anwar et al., 2012; Cabrera et al., 2001). Essential steps are taken before developing performance indicators, including the measurement of student outcomes. Typically, these are communicated to students in the course description, which outlines the course's learning objectives and the faculty's expectations (Hristov et al., 2023). Student outcomes are intended to provide general information about the focus of student learning and are generally stated in terms of outcomes rather than being measurable (Lewis, 2021). Compared

to other indicators, performance indicators are concrete, measurable standards that students must demonstrate as evidence of achievement. Performance indicators are derived from course outcomes (Kennedy, 2008).

Small-enrollment and uneven-enrollment courses pose critical statistical challenges that, in turn, affect the generalizability, reliability, and validity of research results. The fundamental issue arises from a small sample size (low statistical power) and the possibility of unreliable data (Button et al., 2013). There are several critical statistical issues, but low statistical power is the most significant due to a decreased ability to detect an actual effect or difference (Type II error) (Anderson & Maxwell, 2017). The situation suggests that a significant improvement in the course, such as a new teaching method, might be deemed "not statistically significant" given a very small sample size. Results from a

small, specific student group may not accurately reflect the traits of a larger, more diverse population. Compromised external validity makes it difficult to apply the conclusions to other contexts (Mascha & Vetter, 2018).

The Bayesian Hierarchical Modeling (BHM) framework is a robust statistical technique designed to overcome the challenges of small and uneven courses, leveraging data at multiple levels (e.g., students nested within courses, courses nested within departments) to produce more stable and reliable estimates (Berry et al., 2013). The BHM method is particularly applicable in educational environments where traditional statistical methods yield unreliable results with small sample sizes (Vandendijck et al., 2016). Bayesian statistics form the basis of the BHM framework, which uses prior information and observed data to update the probability of an outcome (Moeyaert et al., 2017). Its critical feature in this context is a hierarchical structure modeled at several levels (McGlothlin & Viele, 2018). For instance, student performance is at level 1, a specific course is at level 2, which is nested within a department or institution at level 3. This facilitates information sharing across courses and departments.

Notwithstanding the vast amount of literature on learning outcomes assessment and program evaluation, there still appears to be a methodological gap in the modeling of course-level performance as it relates to hierarchical organization and differential enrollment. This study seeks to fill this methodological gap by formalizing a Bayesian hierarchical model that partitions variance, scales course-level effects via partial pooling, and integrates uncertainty into the evaluation inference. The majority of course-level performance assessments at the institutional level are typically descriptive and based on course averages or threshold comparisons that are, in essence, based on assumptions of independence and equal reliability of courses, and do not typically involve uncertainty estimation or variance decomposition. Although presented in the context of an academic program, the significance of this work lies in the development of a transferable modeling paradigm for learning analytics and educational measurement.

Theoretical Framework

Higher education professionals recognize the use of various assessments, from standardized test scores as sources of information to final course grades for students (Chan, 2014). In measuring reliability, consistency of scores is pertinent. At the same time, validity refers to the support for the interpretations that justify the appropriate use of assessment data, ensuring that it measures what it intends to measure (Birenbaum, 2007). The framework for discussing reliability and validity is widely accepted as the standard for guiding practitioners in quality assurance for the development and use of assessments. The increasing importance of higher education and learning in evolving work patterns and society is broadly acknowledged (Ramezani & Mostafavi, 2025). However, sustaining and implementing educational reform presents significant challenges.

The concept of hierarchy in educational organizations is a fundamental factor in the effective functioning of organizational structures. Hierarchy plays a crucial role in defining authority and tasks across management levels, as

well as in coordinating among them (Baartman et al., 2007). Accountability and task distribution are based on a structure that enables educational institutions to more easily attain strategic objectives, significantly increasing organizational efficiency (Inglis, 2008). Additionally, a hierarchical structure in educational institutions facilitates leadership and decision-making processes, enabling the implementation of a more systematic and structured assessment method (Whiting et al., 2017). A rational management approach facilitates a more efficient decision-making process.

Intra-organizational communication and innovation are negatively impacted by rigid hierarchical structures, making it challenging for faculty members to effectively communicate their assessment ideas and suggestions to senior management (Bentley et al., 2017). This constraint hinders evaluation flexibility and course outcomes. Thus, a balanced hierarchical structure in an educational organization is crucial for maintaining organized assessment and offering flexibility in evaluating learning outcomes (Birenbaum, 2007). The effectiveness of the assessment process, as well as support for faculty participation and motivation, increases in a balanced hierarchical structure (Kruiger & Leuro, 2015, September).

Assessment is deliberately administered and aligned with standards and curriculum; faculty gain a deeper understanding of student progress (Whiting et al., 2017). Similar to curriculum, assessments must align with content and grade-specific requirements to evaluate students' knowledge, skills, and abilities as described in the standards (Chan, 2014). Notably, it is crucial to determine whether the curriculum aligns with the standards and whether the assessments do as well (Feiler et al., 2012). Evaluation does not focus solely on large-scale summative assessments; it also considers formative processes within classrooms and other administered assessments, all of which must be aligned with the curriculum. Alignment with the curriculum involves gathering information pertinent to the specific learning outcomes that students are engaging with.

The four-level model, highly used as an evaluation tool in educational programs, is Kirkpatrick's model of reaction, learning, behavior, and results (Smidt et al., 2009). The first level of the model is applied to formal education settings, encompassing reaction criteria such as the delivery of learning objectives, student learning design, and perceptions (Praslova, 2010). Level two is the learning criteria, which include measuring student performance through skill demonstrations and knowledge tests. Behavioral criteria are the third level of a student's transfer of skills or knowledge beyond the context in which initial learning happened. Result criteria are the final level, which describes long-term outcomes related to service to society, personal stability, and career success (Cheung et al., 2023). Kirkpatrick's first two levels primarily focused on areas in course evaluation, measuring student learning within the specified timeframe (Thörn et al., 2022). In addition to evaluating educational programs, foundational measures are used to assess student reactions to the learning experience. Student attitudes and responses to the delivery and design of learning experiences are used mainly in program evaluation and have been shown to influence learning outcomes (Nawaz et al., 2022).

The methodological basis of this research utilizes Bayesian hierarchical theory as a mathematical model

of information exchange in uncertain contexts. This shrinkage procedure is more than statistical regularization; it implements a normative guideline in evaluation theory, with estimates corresponding to the strength of evidence. Hierarchical Bayes offers a theoretically grounded approach to small-sample problems of instability by shrinking group estimates toward a population mean in proportion to their posterior uncertainty.

This approach redirects educational evaluation from exercises in ranking to uncertainty-calibrated decision-making. This informs methodological debates in learning analytics and educational measurement. It formulates course-level evaluation as probabilistic structural inference. The approach challenges descriptive aggregation and individualistic conceptions of learning achievement. Through the integration of reliability theory, variance decomposition, and Bayesian partial pooling, this research contributes to a methodological integration for learning assessment.

Materials and Methods

Research Design and Framework

Bayesian hierarchical modeling (BHM) is a statistical method used to measure variability at both the individual and group levels, considering prior data to inform analyses and quantify uncertainty in estimates (Baldwin & Fellingham, 2013). BHM is a statistical technique used to analyze data with a multi-level or nested structure, such as students within a course or data gathered from various studies in a meta-analysis (Schmid & Brown, 2000). As a key feature and mechanism, the hierarchical structure recognizes data organized into levels, facilitating parameter estimation at each layer of the hierarchy (Columb & Atkinson, 2016).

Simultaneously, the model assesses students' performance and the average performance of their academic programs. Bayes' theorem forms the basis of BHM, which updates prior beliefs or current knowledge by conditioning on new data and parameters, yielding a full probability distribution (the posterior distribution) for each parameter (Chen et al., 2014). An essential advantage of BHM is the partial pooling of groups with limited data, allowing them to borrow information from the general population distribution (Goodhue et al., 2006, January). This results in more reliable and stable estimates for smaller groups while avoiding overgeneralization from larger groups (Anderson & Maxwell, 2017). Rather than relying on a single point estimate, BHM offers a range of probable values and uncertainty for each parameter, providing a more complete perspective on the results.

In cases where different grading scales were used, categorical grades were transformed into percentage equivalents according to institutional guidelines to facilitate comparison across courses. The main outcome variable, *cor_average*, measures the course-level student performance index based on official institutional grade data for the 2024–2025 academic year. It captures the average student performance score for each course on a continuous scale from 0 to 100. Notably, the variable measures academic performance based on institutional grading systems rather than external standards of competence or ability. Using the standardized model, the variable is converted into z-scores

to enable hierarchical analysis and interpretation of course-level effects in terms of deviations from the grand mean. In the unstandardized model, *cor_average* measures absolute average academic performance, with higher scores indicating better aggregate course performance.

However, several limitations apply. As a course-level aggregate variable, *cor_average* may obscure differences in instructional design and variability in grading practices at the instructional level. The variable does not account for within-course variability or dynamics over time. Therefore, it is considered a structural performance metric within the institutional setting rather than a direct causal indicator of instructional quality.

Data Sources and Collection

The final dataset comprises anonymized student-level performance records derived from official academic assessment data for the BS Business Administration program. A total of 279 students enrolled in the 2024–2025 academic year, across 22 courses, were included in the observations. Each observation represents a student's performance metric, aggregated at the course level, such as a correlation-based or standardized outcome measure, with course identifiers defining group membership. This study utilized anonymized secondary academic records and did not require direct contact with students or the collection of personally identifiable information. In keeping with institutional research standards for minimal-risk studies using de-identified data, formal ethics board approval was not required, and all data were handled in accordance with data protection and confidentiality standards. Courses with very small enrollments were retained initially to diagnose instability and were subsequently pooled in a refined specification that ensures statistically defensible estimation.

Model Specification

The primary model is a Bayesian random-intercept model (Ha et al., 2014) specified as

$$Y_{ij} = \beta_0 + \mu_j + \epsilon_{ij}$$

Where Y_{ij} denotes the outcome for student i in course j , β_0 is the grand mean, $\mu \sim N(0, \tau^2)$ captures the course-level random effect, and $\epsilon_{ij} \sim N(0, \sigma^2)$ represents the course residual variation. Weakly informative priors were used for fixed effects and variance components to stabilize estimation without imposing strong assumptions (Moeyaert et al., 2017). A second, refined specification pooled minimal enrollment courses into a single group, enabling more substantial shrinkage and reducing spurious extremity in course-level estimates.

Estimation and Computation

Model estimation was performed using MCMC sampling via the *stan_lmer* implementation, with 4,000 to 8,000 posterior samples drawn across multiple chains (Monnahan et al., 2017). This method provides complete posterior distributions for all parameters, thereby enabling probabilistic interpretation of course effects and their

uncertainty (Bocquel et al., 2013). Computation focused on achieving stable posterior exploration (Nguyen et al., 2018), with sufficient warm-up iterations and thinning avoided to preserve an adequate sample size (Kim et al., 2017).

Model Validation and Checking

A combination of convergence diagnostics and posterior predictive checks was used to assess model adequacy. Convergence was evaluated using both the potential scale reduction factor (Stern & Sinharay, 2005) and Monte Carlo standard errors, as well as effective sample size (Koch, 2018), all of which indicated excellent convergence ($R\text{-hat} < 1.01$ for all parameters) (Chen et al., 2025). For model adequacy, posterior predictive distributions were examined to ensure that the key features of the observed data were accurately replicated, with a focus on the overall mean and dispersion (Gajewski et al., 2008). Comparisons of unpooled and pooled specifications were used to assess the effects of partial pooling on stability and interpretability (Feng et al., 2024).

From a Bayesian viewpoint, statistical strength is assessed through the concentration of posterior distributions and the stability of credible intervals. Courses with larger enrollment sizes have narrower intervals and higher posterior precision, while small-enrollment courses have wider intervals and stronger shrinkage toward the grand mean. This adaptive borrowing of strength partially offsets the problem of small sample sizes but does not eliminate imprecision in sparse groups.

Limitations of Methodology

A drawback of the study design is that the number of courses and students limits the precision of estimates for individual courses, particularly for small classes. While hierarchical shrinkage reduces imprecision, some posterior intervals remain wide, suggesting that there is only limited evidential support for precise comparisons. Future studies with multiple years of data across several institutions would greatly improve inferential precision and allow more robust structural inferences.

The study uses data from complete institutional records for a single year; no classical a priori power analysis was necessary, as the size of the enrollment was determined by administrative necessity rather than experimental design. In Bayesian hierarchical analysis, goodness of fit is assessed through the precision of posterior distributions, effective sample size, and interval width rather than null hypothesis-based power calculations. The total sample ($N = 279$ across 22 courses) is sufficient to provide information for the estimation of overall variance components, although precision for individual courses varies proportionally with enrollment size.

Results

The descriptive statistics in Table 1 indicate that student performance is highly dispersed across the BS Business Administration program. While the overall mean is 72.79 and the median is noticeably higher at 79.44, the large standard deviation of 22.32 and the full range of 0 to 100

depict strong heterogeneity in outcomes. At the course level, this noticeable average enrollment is reasonable (about 13 students per course), yet the courses cover a wide range from 1.69 to a perfect 100. This array suggests that raw differences in performance cannot be attributed solely to differences in student performance, but rather reflect structural differences across courses in alternative assessments and evaluation practices. These descriptive results from the observed motivation for the subsequent multilevel evaluation, due to basic aggregation, clearly mask the principal effects of the course and exacerbate instability arising from small enrollments.

Table 1. Descriptive Statistics of Student Performance

Statistic	Value
Number of Observations	279
Number of courses	22
Mean	72.79
Median	79.44
Standard Deviation	22.32
Minimum	0
Maximum	100
Average student per course	12.7
The range of the course means	1.69-100

The variance decomposition in Table 2 clearly indicates a structural imbalance in the BS Business Administration program, with nearly 69% of the total performance variability explained by between-course rather than within-course variability, resulting in a high ICC of 0.688. This implies that the program the student attends is far more important than the student. This level would not be expected in an optimally integrated academic program, indicating significant variability in the standards and performance measures across courses. The minor variability within courses suggests that, once students are grouped in the same course, their performance tends to be relatively similar, confirming the observation that course-level factors largely determine performance.

Table 2. Variance Components and Descriptive Summary
Variance Components Decomposition

Component	Variance	Percentage	ICC
Between Course	776.06	68.78	0.688
Within-Course	352.33	31.22	-
Total	497.97	100	-

Descriptive statistics in Table 1 confirm this diagnosis: although the grand mean is 72.79, the class means exhibit an extreme range, from 1.69 to 1.00, despite the average class size being only about 13 students. This combination of small enrollments with extreme means is a red flag. It maximizes course effects and inflates between-course variance, to make some courses appear “excellent” artificially and others catastrophically weak. The results taken together suggest a quality assurance problem at the program level rather than one related to isolated student underperformance and, again, call for tighter alignment of assessment criteria, stronger

moderation of grading practices, and closer monitoring of low- and high-outlier courses as a way of restoring equity and defensibility in academic outcomes.

The Bayesian random-intercept models in Table 3 show that course membership is a primary structural driver of variation in the outcome-cor_average. The overall intercept represents a baseline latent mean, while the significant, estimated course-level variance ($\approx 1,416$) relative to the residual variance ($\sigma \approx 18.9$) suggests substantial heterogeneity across courses. Several courses, particularly 3_ENTE 222, 3_FM 211, and selected GE offerings, exhibit significant positive deviations from the grand mean, whereas 3_FME 311, 3_FME 322, and 3_FM 221 show significant adverse effects with credible intervals that exclude zero. The result suggests that these courses have systematically lower outcomes, rather than experiencing random fluctuations. This set of results aligns with the earlier variance decomposition results, as most of the variation is between courses rather than within them.

Table 3. Bayesian Random-Intercept Model (Unpooled Courses) Fixed Effect (Overall Intercept)

Parameter	Mean	SD	2.50%	97.50%
Intercept (Grand Mean)	42.14	9.49	1.82	58.14

Table 4. Course-Level Random Effect (Selected)

Course	Mean	SD	2.50%	97.50%
3_ENTE 222	44.73	20.47	7.5	86.32
3_FM 211	46.12	12.37	23.55	71.17
3_GE 5	40.83	12.76	17.07	66.07
3_GE 7	39.39	10.82	20.08	62.36
3_GE 9	38.89	19.87	0.85	79.88
3_FM 221	-24.02	14.41	-51.71	5.11
3_FME 311	-34.19	14.45	-61.55	-4.88
3_FME 322	-34.49	14.06	-60.83	-6.01

Positive values indicate above-grand mean performance, negative values indicate below-grand mean performance

Table 5. Variance Component

Component	Mean	SD	2.50%	97.50%
Residual SD (σ)	18.87	0.83	17.35	20.56
Course Level Variance	1415.68	751.9	462.54	3378.2

Table 6. Posterior Predictive Check

Statistic	Mean	SD	2.50%	97.50%
Mean_PPD	72.21	1.62	69.04	75.29

Table 7. MCMC Diagnostics (Summary)

Metric	Result
Rhat (all parameters)	≈ 1.00 -1.01
Effective Sample Size	500-3900
MCSE	Small relative to posterior SD
Convergence	Satisfactory

From the point of view of model quality, diagnostics are clean: The Rhat values are all essentially 1; effective sample

sizes are good; and the posterior predictive check shows that the model reproduces the observed mean very well (mean PPD ≈ 72.2 , close to the empirical average). The hierarchal estimates provide information on relative location within the sample and the degree of uncertainty associated with these locations, rather than suggesting direct causal links between course organization, teaching, and policy decisions and the observed differences. The estimates presented are measures of statistical association within the observed grading pattern and are not considered for causal interpretation. The variance and random effects for the between course levels capture patterns of dispersion in the measured performance under the grading structure of the institution.

Table 8. Bayesian Random-Intercept Model with Pooled Small Courses. Fixed Effect (Overall intercept)

Parameter	Mean	SD	2.50%	50.00%	97.50%
Intercept	0.018	0.157	-0.293	0.018	0.322

Table 9. Course-Level Random Effects

Course	Mean	SD	2.50%	97.50%	Interpretation
3_FM_211	0.48	0.331	-0.135	1.171	Moderately positive, uncertain
3_GE 1	0.206	0.19	-0.167	0.58	Small positive
3_GE 11	0.136	0.289	-0.43	0.705	Weak, inconclusive
3_GE 2	-0.305	0.376	-1.077	0.404	Weak negative
3_GE 20	0.271	0.258	-0.23	0.796	Small positive
3_GE 3	-0.136	0.205	-0.545	0.268	Near zero
3_GE 4	-0.604	0.211	-1.028	0.2	Credible negative effect
3_GE 5	0.32	0.335	-0.312	0.999	Positive, uncertain
3_GE 6	-0.322	0.235	-0.782	0.131	Weak negative
3_GE 7	0.319	0.264	-0.197	0.652	Small positive
3_GE 8	0.234	0.2	-0.151	0.641	Small positive
3_UGE 1	0.155	0.236	-0.319	0.626	Near zero
3_UGE 2	0.211	0.268	-0.307	0.741	Small positive
POOLED_SMALL COURSES	-0.962	0.281	-1.537	-0.432	Strong negative effect

Table 10. Variance Components

Component	Mean	SD	2.50%	97.50%
Residual SD (σ)	0.917	0.041	0.641	1.001
Couse-Level Variance	0.27	0.154	0.088	0.663

Table 11. Posterior Predictive Check

Statistic	Mean	SD	2.50%	50%	97.50%
Mean_PPD	-0.0004	0.078	-0.153	-0.001	0.153

Table 12. MCMC Diagnostic (Summary)

Metric	Result
Max R-hat	1.0029
Convergence	Excellent (all < 1.01)
Effective Sample Size	1,700-8,200
MCSE	Negative relative to SD

The overall intercept depicted in Table 4 is essentially zero, indicating that `cor_average` is now correctly centered. Consequently, course effects are interpreted as deviations from a neutral baseline, rather than being inflated by scale artifacts. Course-level variance is substantially reduced compared with the earlier model, confirming that much of the previously observed between-course extremity was driven by sparse data rather than genuine structural differences. Most individual courses have credible intervals that overlap zero, indicating their effects are statistically indistinguishable from the program average after controlling for slight sample instability.

Two results clearly stand out and are defensible. First, `3_GE 4` demonstrates a credibly negative effect, as its entire 95% credible interval falls below zero, indicating systematically weaker outcomes. Even after pooling and shrinkage, this conveys a substantive signal rather than noise. Second, the `POOLED_SMALL_COURSES` group shows a large and robust negative effect, confirming that very small-enrollment courses, when combined, consistently underperform relative to the program norm. Model diagnostics are exemplary, with R -hat values near 1, high effective sample sizes, and good posterior predictive checks, indicating excellent reproduction of the observed mean. This model is statistically clean and stable; substantially, it narrows the problem from “many extreme courses” to a focused set of underperforming course

structures, thus offering a far stronger basis for academic review, policy action, and defensible reporting.

Figure 1 below shows the posterior distributions of rank correlations (ρ) by course. The message is blunt: while only a handful of courses display extreme, degenerate posteriors, most cluster tightly around zero. Several major-field courses, notably FM and MM, and selected ENTE/FME subjects, produce razor-thin spikes at $\rho = +1$ or $\rho = -1$, suggesting that practically deterministic monotonic relationships are statistically suspicious and due to small samples, limited score dispersion, or structurally constrained grading rather than accurate, perfect alignment. By contrast, the General Education (GE) and University GE (UGE) courses present bell-shaped posteriors centered close to zero with relatively narrow spreads, which imply weak to modest associations and greater heterogeneity in student performance, precisely what one would want from service courses taken by diverse cohorts. A few of the GE subjects do lean positive or negative, but one is as extreme as those from major courses. Overall, the figure reinforces a clear structural pattern within the BS Business Administration Program: high correlation stability exists only where assessment and enrollment are tightly controlled. At the same time, most courses contribute independently to student outcomes, and any interpretation of “perfect” correlation should be viewed as a data artifact rather than evidence of curricular inevitability.

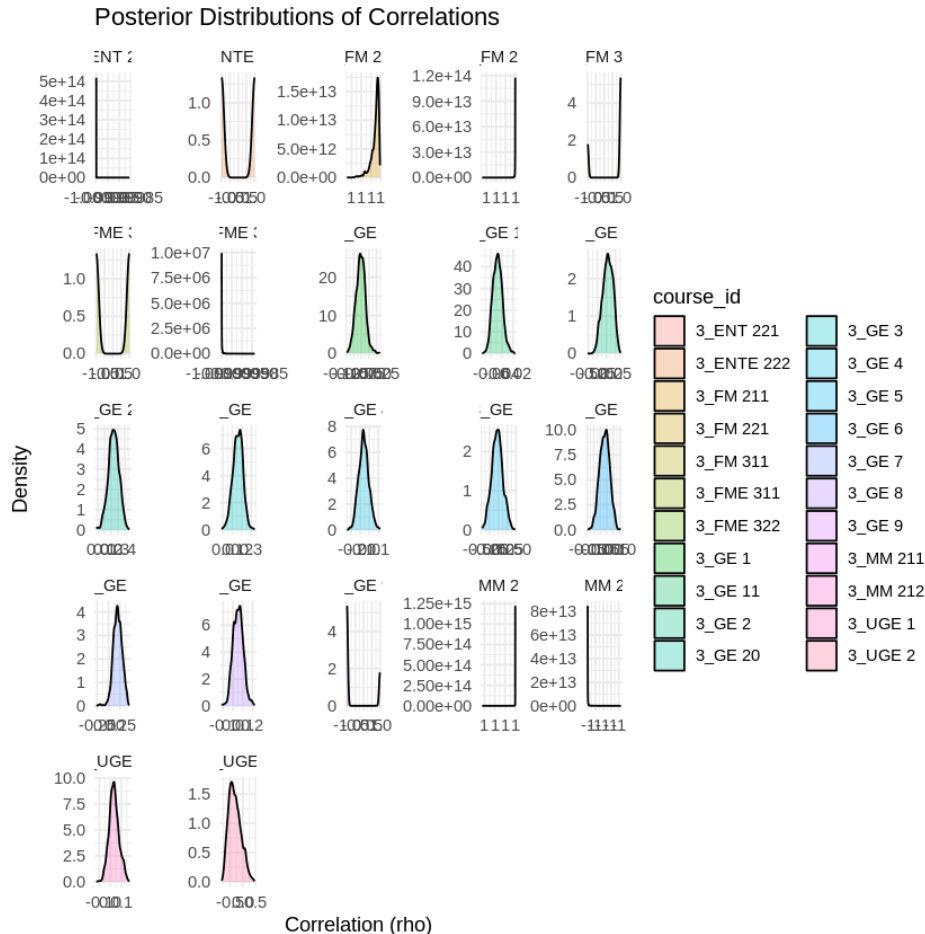


Fig. 1 Posterior Distribution of Course-Level Correlations

Figure 2 below shows a caterpillar plot of posterior course-level random effects from a Bayesian hierarchical model. Points are posterior means, and horizontal bars are 95% credible intervals, all centered around the red dashed zero line, which represents the grand mean. Most course clusters tightly around zero, with their intervals overlapping the reference line, indicating that, controlling for overall variability. These are not statistically distinguished from the program average. In contrast, a small subset of courses exhibits decidedly negative effects. For instance, courses 3_FME 311 and 3_FME 322 are identified as having credible intervals that lie completely below zero, suggesting systematic underperformance rather than random fluctuations. Several courses have positive effects, such as 3_FM 211 and 3_ENTE 222, as well as some GE courses. However, the wide intervals associated with those estimates reflect significant uncertainty, primarily driven by small enrollments. The wide interval for the course-level variance parameter indicates substantial heterogeneity across courses overall. Figure 2 supports the notion that, despite variation between courses, few courses exhibit credibly different performance, which in turn supports the need for pooled estimation and targeted academic review rather than broad program-level conclusions.

Figure 3 reveals a striking and concerning pattern in the data: the most extreme course means, both very high and very low, are concentrated in courses with very small enrollments. At the same time, larger classes cluster tightly around the grand mean, represented by the dashed line at approximately 73. Courses with one to three students exhibit wildly inflated means near 100, or else collapsed means close to zero that are statistically unstable and almost certainly. Courses with one to three students exhibit wildly inflated means near 100, or else collapsed means close to zero, which are statistically unstable and almost certainly reflect grading idiosyncrasies or data artifacts rather than actual instructional effectiveness or failure. As the sample size increases, the course means regress toward the grand mean, and mid- to large-enrollment courses show far less dispersion and more credible performance estimates. This pattern directly explains the high between-course variance and significant random effects observed earlier: small-n courses are driving artificial polarization in outcomes. In practical terms, the figure makes it evident that unmoderated small classes are distorting program-level performance metrics, and any evaluative or accountability use of course means without adjusting for enrollment size would be methodologically indefensible.

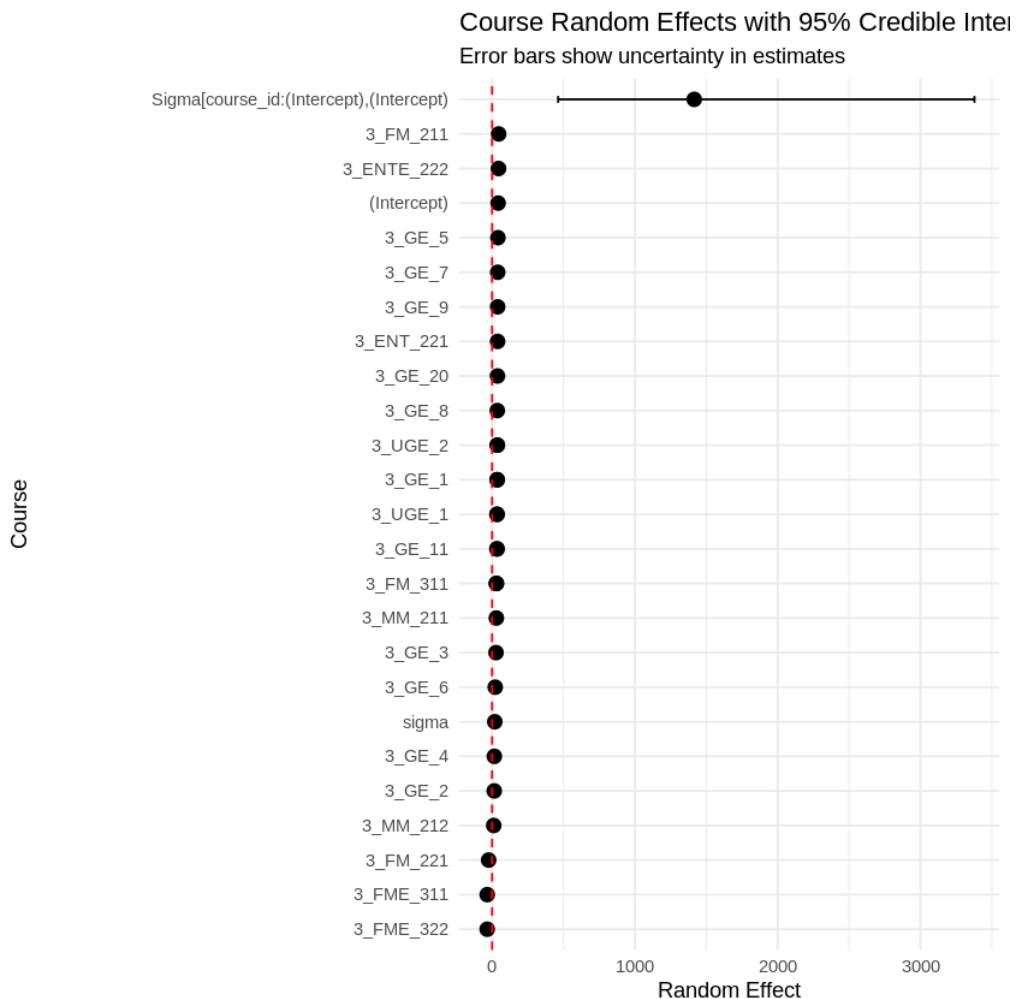


Fig. 2. Course Random Effects with 95% Credible Intervals

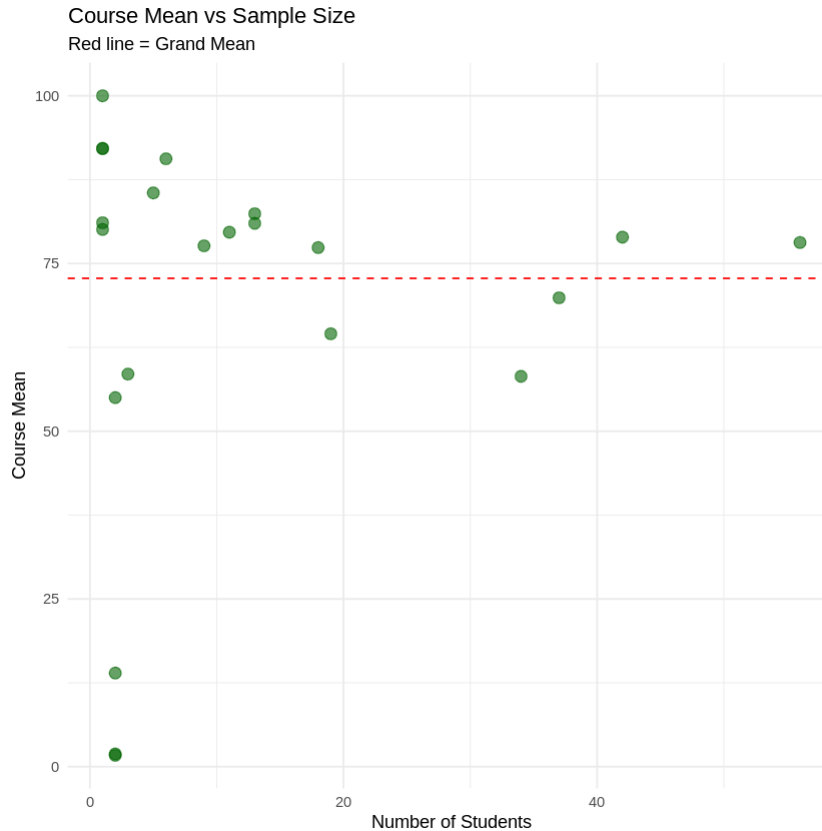


Fig. 3. Course Mean vs Sample Size

Discussions

The study describes structural differences in aggregated performance metrics rather than providing normative judgments about teaching effectiveness, course quality, or administrative efficacy. Within the Bayesian hierarchical framework, a credible interval that does not include zero indicates statistical distinction in model-based estimation, rather than evidence of instructional superiority or deficiency. Accordingly, the identified course-level effects represent probabilistic deviations from the program mean, explicitly adjusted for sampling uncertainty and uneven enrollment, and should be interpreted as properties of the measurement structure rather than causal attributes of courses or instructors.

This interpretation is reinforced by caterpillar plots of random effects, in which courses are positioned relative to the grand mean. Variance component estimates and consistently high intraclass correlation coefficients indicate that a substantial proportion of observed variability is expressed at the course level rather than arising from differences among students within the same course (Yang Hansen et al., 2024). Importantly, this does not imply that course-level factors are causal determinants of student performance. Instead, it reflects the structuring of assessment and grading practices within the observed institutional context, a pattern that has also been noted in prior analyses of performance differences in educational systems (Gyamfi et al., 2022).

At the same time, the joint inspection of course-level effects and enrollment size highlights a second critical

issue: statistical instability associated with small samples. Small classes are not only noisier; under naïve aggregation, they produce unstable estimates that can distort program-level inference (Allenby & Rossi, 2006). Courses with very small enrollments exhibit extreme means and wide credible intervals, creating the appearance of exceptional performance or underperformance that is largely driven by sparse data. These patterns account for the inflated between-course variance observed in the unpooled model and demonstrate the limitations of direct comparisons based on raw course averages. The wide posterior uncertainty associated with these estimates further confirms that they should not be interpreted as reliable indicators of substantive instructional differences but rather as manifestations of estimator instability (Mascha & Vetter, 2018).

Methodologically, the application of Bayesian hierarchical pooling reframes course-level evaluation from descriptive comparison to statistically grounded inference. Partial pooling reduces spurious extremity by shrinking imprecise estimates toward the program mean while preserving differences supported by sufficient evidence. In the pooled specification, most course effects contract toward zero and lose apparent distinctiveness, whereas a limited subset retains consistent deviations, indicating structurally meaningful differences. In this sense, hierarchical modeling functions as a filtering mechanism that distinguishes structural signal from measurement noise and aligns course-level evaluation with principles of uncertainty-aware inference (Greenland et al., 2016).

Conclusions

This study concludes that students' performance in the BS Business Administration program is primarily determined by structures at the course level rather than by individual student differences. Consequently, a significant proportion of the variability between courses is attributed to how courses are structured, assessed, and taught. It also shows that raw comparisons between courses are highly unreliable when enrollments are small because sparse data inflate apparent extremes and mask actual instructional effects. These distortions are corrected through Bayesian hierarchical pooling, which shrinks and stabilizes unstable estimates without eliminating credible signals of systematic underperformance in the small set of identified courses. The evidence supports targeted, course-specific academic reviews rather than broad or punitive program-wide interventions, emphasizing that sound methodological choices are essential to fair and defensible evaluations. Overall, the study indicates that meaningful program assessment requires both recognition of structural course effects and statistical discipline in handling small-sample variability.

Although hierarchical modeling offers a more statistically informed framework for understanding structural differences in course-level performance, any administrative or policy intervention would necessarily require additional qualitative and contextual information beyond the scope of the current analysis.

The study suggests that courses with a persistent negative effect after Bayesian pooling, such as 3_FME 311 and 3_FME 322, should be considered within a broader curricular reform and intervention strategy. These courses exhibit a strong negative random effect, with credible intervals below zero, suggesting they are high-priority candidates for immediate academic review in instructional delivery, content alignment, grading standards, and assessment design. Moreover, 3_GE 4, despite shrinkage, remains negative and requires similar attention, indicating the presence of structural issues rather than sampling noise. Courses in the POOLED_SMALL_COURSES category that are not individually evaluated should be addressed through policy measures aimed at consolidating courses and standardizing assessment frameworks. On the other hand, courses such as 3_FM 211, 3_ENTE 222, and 3_ENTE 221 exhibit a significant positive effect, albeit with considerable uncertainty, and require further validation before being considered benchmarks of excellence. This is due to the potential for student performance estimates to be biased by small sample sizes. The recommendations include initiating diagnostic reviews and implementing uniform assessment procedures for underperforming courses, establishing regular program evaluation to institutionalize hierarchical modeling, and preventing decision-making based on unadjusted course means.

Ethical Considerations

This study is based exclusively on anonymized secondary academic records obtained from official institutional assessment data. No personally identifiable information was accessed, collected, or processed at any stage of the research. The dataset was fully de-identified prior to analysis, and individual students cannot be re-identified from the reported results.

In accordance with institutional research guidelines for minimal-risk studies using de-identified administrative data, formal ethics committee approval was not required. All procedures complied with applicable standards for data protection, confidentiality, and responsible research conduct.

Data Availability

The data supporting the findings of this study consist of anonymized institutional academic records and are subject to confidentiality and data protection restrictions imposed by the hosting institution. Therefore, the raw data are not publicly available.

Aggregated data summaries, model specifications, and analytical procedures necessary to reproduce the reported results are described in sufficient detail within the manuscript. Reasonable requests for additional methodological clarification may be considered by the corresponding author, subject to institutional approval.

AI Transparency Statement

The authors declare that no generative artificial intelligence (AI) tools were used for data generation, statistical analysis, or result interpretation. Computational modeling and statistical inference were conducted using established statistical software and fully specified Bayesian procedures.

AI-based tools may have been used solely for language editing or stylistic refinement of the manuscript text. Such use did not influence the scientific content, data analysis, interpretation of results, or conclusions of the study. The authors retain full responsibility for the integrity and originality of the work.

Acknowledgment

The researchers would like to acknowledge the Administration and the Research and Publication Center (RPC) for their assistance, as well as their colleagues for their moral support.

Conflict of interest

None

References

- Anwar, M.A., Ahmed, N., & Al Ameen, A.M. (2012). An Outcome-Based Assessment and Improvement System for Measuring Student Performance and Course Effectiveness. *Contemporary Issues in Education Research*, 5(4), 279-294. <https://doi.org/10.19030/cier.v5i4.7272>
- Cabrera, A.F., Colbeck, C.L., & Terenzini, P.T. (2001). Developing performance indicators for assessing classroom teaching practices and student learning. *Research in higher education*, 42(3), 327-352. <https://doi.org/10.1023/A:1018874023323>
- Hristov, S., Nakov, D., & Miočinović, J. (2023). Constructive alignment between objectives, teaching and learning activities, student competencies and assessment methods in higher education. *Journal of Agriculture and Plant Sciences*, 21(2), 21-36. <https://doi.org/10.46763/JAPS23212021h>

- Lewis, E. (2021). Best practices for improving the quality of the online course design and learners experience. *The Journal of Continuing Higher Education*, 69(1), 61-70. <https://doi.org/10.1080/07377363.2020.1776558>
- Kennedy, D. (2008). Linking Learning Outcomes and Assessment of Learning of Student Science Teachers. *Science Education International*, 19(4), 387-397. https://eric.ed.gov/?id=EJ890648&utm_source=chatgpt.com
- Button, K.S., Ioannidis, J.P., Mokrysz, C., Nosek, B.A., Flint, J., Robinson, E.S., & Munafò, M.R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature reviews neuroscience*, 14(5), 365-376. <https://doi.org/10.1038/nrn3475>
- Anderson, S.F., & Maxwell, S.E. (2017). Addressing the “replication crisis”: Using original studies to design replication studies with appropriate statistical power. *Multivariate behavioral research*, 52(3), 305-324. <https://doi.org/10.1080/00273171.2017.1289361>
- Mascha, E.J., & Vetter, T.R. (2018). Significance, errors, power, and sample size: the blocking and tackling of statistics. *Anesthesia & Analgesia*, 126(2), 691-698. <https://doi.org/10.1213/ANE.0000000000002741>
- Berry, S.M., Broglio, K.R., Groshen, S., & Berry, D.A. (2013). Bayesian hierarchical modeling of patient subpopulations: efficient designs of phase II oncology clinical trials. *Clinical Trials*, 10(5), 720-734. <https://doi.org/10.1177/1740774513497539>
- Vandendijck, Y., Faes, C., Kirby, R.S., Lawson, A., & Hens, N. (2016). Model-based inference for small area estimation with sampling weights. *Spatial Statistics*, 18, 455-473. <https://doi.org/10.1016/j.jspasta.2016.09.004>
- Moeyaert, M., Rindskopf, D., Onghena, P., & Van den Noortgate, W. (2017). Multilevel modeling of single-case data: A comparison of maximum likelihood and Bayesian estimation. *Psychological Methods*, 22(4), 760. <https://doi.org/10.1037/met0000136>
- McGlothlin, A.E., & Viele, K. (2018). Bayesian hierarchical models. *Jama*, 320(22), 2365-2366. <https://doi.org/10.1001/jama.2018.17977>
- Chan, E.K. (2014). *Standards and guidelines for validation practices: Development and evaluation of measurement instruments*. In Validity and validation in social, behavioral, and health sciences (pp. 9-24). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-07794-9_2
- Birenbaum, M. (2007). Evaluating the assessment: Sources of evidence for quality assurance. *Studies in Educational Evaluation*, 33(1), 29-49. <https://doi.org/10.1016/j.stueduc.2007.01.004>
- Ramezani, S.G., & Mostafavi, Z.S. (2025). Developing and validating a comprehensive scale for accreditation standards and quality assurance in e-learning institutions. *Education and Information Technologies*, 1-49. <https://doi.org/10.1007/s10639-025-13587-5>
- Baartman, L.K., Bastiaens, T.J., Kirschner, P.A., & Van der Vleuten, C.P. (2007). Evaluating assessment quality in competence-based education: A qualitative comparison of two frameworks. *Educational research review*, 2(2), 114-129. <https://doi.org/10.1016/j.edurev.2007.06.001>
- Inglis, A. (2008). Approaches to the validation of quality frameworks for e-learning. *Quality Assurance in Education*, 16(4), 347-362. <https://doi.org/10.1108/09684880810906490>
- Whiting, P., Wolff, R., Mallett, S., Simera, I., & Savović, J. (2017). A proposed framework for developing quality assessment tools. *Systematic reviews*, 6(1), 204. <https://doi.org/10.1186/s13643-017-0604-6>
- Bentley, T.G., Cohen, J.T., Elkin, E.B., Huynh, J., Mukherjea, A., Neville, T.H., ... & Broder, M.S. (2017). Validity and reliability of value assessment frameworks for new cancer drugs. *Value in Health*, 20(2), 200-205. <https://doi.org/10.1016/j.jval.2016.12.011>
- Kruger, T., & Leuro, J. (2015, September). *Using Quality Assurance Principles to Help Ensure the Validity and Reliability of Competency Assessments*. In SPE Offshore Europe Conference and Exhibition (pp. SPE-175491). SPE. <https://doi.org/10.2118/175491-MS>
- Feiler, P.H., Goodenough, J.B., Gurfinkel, A., Weinstock, C.B., & Wrage, L. (2012). *Reliability validation and improvement framework* (No. CMUSEI2012SR013). https://www.sei.cmu.edu/documents/1918/2012_003_001_34081.pdf
- Smidt, A., Balandin, S., Sigafoos, J., & Reed, V.A. (2009). The Kirkpatrick model: A useful tool for evaluating training outcomes. *Journal of Intellectual and Developmental Disability*, 34(3), 266-274. <https://doi.org/10.1080/13668250903093125>
- Praslova, L. (2010). Adaptation of Kirkpatrick's four level model of training criteria to assessment of learning outcomes and program evaluation in higher education. *Educational assessment, evaluation and accountability*, 22(3), 215-225. <https://doi.org/10.1007/s11092-010-9098-7>
- Cheung, V.K. L., Chia, N.H., So, S.S., Ng, G.W. Y., & So, E.H. K. (2023). Expanding scope of Kirkpatrick model from training effectiveness review to evidence-informed prioritization management for cricothyroidotomy simulation. *Heliyon*, 9(8). <https://doi.org/10.1016/j.heliyon.2023.e18268>
- Thörn, J., Strandberg, P.E., Sundmark, D., & Afzal, W. (2022). Quality assuring the quality assurance tool: applying safety-critical concepts to test framework development. *PeerJ Computer Science*, 8, e1131. <https://doi.org/10.7717/peerj-cs.1131>
- Nawaz, F., Ahmad, W., & Khushnood, M. (2022). Kirkpatrick model and training effectiveness: a meta-analysis 1982 to 2021. *Business & Economic Review*, 14(2), 35-56. <https://doi.org/10.22547/BER/14.2.2>
- Baldwin, S.A., & Fellingham, G.W. (2013). Bayesian methods for the analysis of small sample multilevel data with a complex variance structure. *Psychological methods*, 18(2), 151. <https://doi.org/10.1037/a0030642>
- Schmid, C.H., & Brown, E.N. (2000). Bayesian hierarchical models. *Methods in enzymology*, 321, 305-330. [https://doi.org/10.1016/S0076-6879\(00\)21200-7](https://doi.org/10.1016/S0076-6879(00)21200-7)
- Columb, M.O., & Atkinson, M.S. (2016). Statistical analysis: sample size and power estimations. *Bja Education*, 16(5), 159-161. <https://doi.org/10.1093/bjaed/mkv034>
- Chen, C., Wakefield, J., & Lumely, T. (2014). The use of sampling weights in Bayesian hierarchical models for small area estimation. *Spatial and spatio-temporal epidemiology*, 11, 33-43. <https://doi.org/10.1016/j.sste.2014.07.002>
- Goodhue, D., Lewis, W., & Thompson, R. (2006, January). PLS, small sample size, and statistical power in MIS research. *In Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06)* (Vol. 8, pp.

- 202b-202b). IEEE.
<https://doi.org/10.1109/HICSS.2006.381>
- Monnahan, C.C., Thorson, J.T., & Branch, T.A. (2017). Faster estimation of Bayesian models in ecology using Hamiltonian Monte Carlo. *Methods in Ecology and Evolution*, 8(3), 339-348. <https://doi.org/10.1111/2041-210X.12681>
- Bocquel, M., Papi, F., Podt, M., & Driessen, H. (2013). Multitarget tracking with multiscan knowledge exploitation using sequential MCMC sampling. *IEEE Journal of Selected Topics in Signal Processing*, 7(3), 532-542. <https://doi.org/10.1109/JSTSP.2013.2251317>
- Nguyen, T.D., Gupta, S., Rana, S., & Venkatesh, S. (2018). Stable bayesian optimization. *International Journal of Data Science and Analytics*, 6(4), 327-339. <https://doi.org/10.1007/s41060-018-0119-9>
- Kim, M., Ding, Y., Malcolm, P., Speckaert, J., Sivi, C.J., Walsh, C.J., & Kuindersma, S. (2017). Human-in-the-loop Bayesian optimization of wearable device parameters. *PLoS one*, 12(9), e0184054. <https://doi.org/10.1371/journal.pone.0184054>
- Stern, H.S., & Sinharay, S. (2005). Bayesian model checking and model diagnostics. *Handbook of Statistics*, 25, 171-192. [https://doi.org/10.1016/S0169-7161\(05\)25007-1](https://doi.org/10.1016/S0169-7161(05)25007-1)
- Koch, K.R. (2018). Bayesian statistics and Monte Carlo methods. *Journal of Geodetic Science*, 8(1), 18-29. <https://doi.org/10.1515/jogs-2018-0003>
- Chen, J.J., Lai, P.C., & Huang, Y.T. (2025). Bayesian reanalysis reinforces the potential mortality benefit of TNF- α inhibitors in COVID-19: a methodological perspective. *Critical Care*, 29(1), 250. <https://doi.org/10.1186/s13054-025-05506-4>
- Gajewski, B.J., Simon, S.D., & Carlson, S.E. (2008). Predicting accrual in clinical trials with Bayesian posterior predictive distributions. *Statistics in medicine*, 27(13), 2328-2340. <https://doi.org/10.1002/sim.3128>
- Feng, Y., Gao, K., & Lacasse, S. (2024). Bayesian partial pooling to reduce uncertainty in overcoring rock stress estimation. *Journal of Rock Mechanics and Geotechnical Engineering*, 16(4), 1192-1201. <https://doi.org/10.1016/j.jrmge.2023.05.003>
-

По за межами курсових середніх: узагальнена байєсівська ієрархічна методологічна рамка оцінювання результатів навчання на рівні курсів

Вінсенте Е. Монтано^{1ABCD}, Арчі Г. Рейс^{1ABCD}

¹Університет Мінданао

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 12 с., 12 табл., 3 рис., 40 джерел.

Обґрунтування. Оцінювання результатів навчання на рівні курсів у вищій освіті часто базується на порівнянні середніх показників, що передбачає незалежність курсів та однаково надійність оцінок. За умов малих і нерівномірних контингентів така практика призводить до статистичної нестабільності та перебільшення крайніх значень, ускладнюючи інтерпретацію курсових відмінностей.

Мета. Метою дослідження є обґрунтування узагальненої методологічної рамки застосування байєсівського ієрархічного моделювання (Bayesian hierarchical modeling, ВНМ) для оцінювання результатів навчання на рівні курсів з урахуванням невизначеності та нерівномірності вибірок.

Матеріали і методи. У дослідженні використано ієрархічну байєсівську модель, у якій результати навчання студентів моделюються на індивідуальному рівні з урахуванням їх належності до конкретних курсів, що відображає багаторівневу організацію освітніх даних. Модель передбачає декомпозицію загальної дисперсії на внутрішньокурсову та міжкурсівську складові з оцінюванням курсових ефектів на основі апостеріорних розподілів. Для зменшення спотворень, зумовлених малими обсягами вибірок, застосовано механізм часткового пулінгу. Як емпіричну ілюстрацію використано знеособлені дані про результати навчання 279 студентів у 22 курсах.

Результати. Показано, що наївні порівняння курсів за середніми значеннями систематично перебільшують крайні оцінки за малих обсягів вибірок, формуючи нестабільні та потенційно хибні висновки. Застосування ієрархічного байєсівського підходу з частковим пулінгом суттєво знижує штучну екстремальність оцінок і водночас зберігає структурно обґрунтовані міжкурсівські відмінності.

Висновки. Запропонована методологічна рамка забезпечує статистично обґрунтовану альтернативу описовому агрегуванню та ранжуванню курсів, орієнтуючи оцінювання результатів навчання на ймовірнісну структурну інтерпретацію з урахуванням невизначеності.

Ключові слова: байєсівське ієрархічне моделювання, багаторівневий аналіз, курсовий рівень оцінювання, нестабільність малих вибірок, освітні вимірювання.

Information about the Authors:

Montano, V.E.: vicente_montano@umindanao.edu.ph; <https://orcid.org/0000-0001-9117-568X>; Business Economics Department, College of Business Administration Education, University of Mindanao, Bolton St., 8000, Davao City, Philippines.

Reyes, A.G.: archiereyes@umindanao.edu.ph ; <https://orcid.org/0009-0005-7443-3022>; Human Resource Management Department, College of Business Administration Education, University of Mindanao, Bolton St., 8000, Davao City, Philippines.

Cite this article as: Montano, V., & Reyes, A. (2026). Beyond Course Averages: A Generalized Bayesian Hierarchical Framework for Course-Level Learning Evaluation. *Journal of Learning Theory and Methodology*, 7(1), 37-48.
<https://doi.org/10.17309/jltm.2026.7.1.04>

Received: 17.01.2026. Accepted: 17.02.2026. Published: 30.04.2026

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>)



Gamified Inclusive Physical Education as an Adaptive Rehabilitation Model for University Students with Blast Traumatic Brain Injury

Oksana Blavt^{1ABD}, Gennadii Iedynak^{2BCDE} and Yan Bezhrebelyny^{1BCD}

¹Lviv Polytechnic National University

²Kamianets-Podilskyi National Ivan Ohienko University

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.1.05

Abstract

Background. The ongoing war in Ukraine has increased the number of university students living with disabilities caused by blast traumatic brain injury (TBI). This situation creates an urgent need for inclusive physical education models that combine rehabilitation goals with effective motivational strategies. Gamification may enhance participation, adherence, and functional recovery within adaptive learning environments.

Objectives. The purpose of this study was to determine the effectiveness of a gamified inclusive physical education program as an adaptive rehabilitation model for university students with blast traumatic brain injury.

Materials and Methods. Twenty-eight first-year male students aged 18–23 years with mild blast TBI and mild functional impairment participated in the study. Participants were divided into a control group (n = 14) and an experimental group (n = 14). The control group followed a standard inclusive physical education program, while the experimental group completed a vestibular rehabilitation program integrated with gamification elements. The intervention lasted two academic semesters. Functional changes were assessed using the Lower Quarter Y-Balance Test and the Figure-of-8 Walk Test. Data were processed using descriptive statistics and Student's t-test.

Results. At baseline, no statistically significant differences were observed between groups ($p > .05$). After the intervention, the experimental group demonstrated substantially greater improvements than the control group across all indicators. Gains in the experimental group ranged from 15.3% to 22.1%, while changes in the control group did not exceed 5.7%. The largest effects were observed in walking efficiency, balance control, and coordination performance.

Conclusions. Gamified inclusive physical education can be considered an effective adaptive rehabilitation model for university students with blast traumatic brain injury. The integration of structured physical exercises with motivational game mechanics improved functional outcomes, engagement, and movement confidence. The findings support the use of gamification in inclusive university physical education under conditions of increased rehabilitation demand.

Keywords: inclusive physical education, gamification, traumatic brain injury, adaptive learning, rehabilitation, university students, balance, coordination.

Introduction

The full-scale war in Ukraine has created new challenges for higher education institutions, including a growing number of students living with disabilities caused by combat actions and missile attacks (Klos, Blavt, & Kovalchuk, 2024). Among these conditions, blast traumatic brain injury (TBI) has become one of the most significant because of its complex neurological, vestibular, and functional consequences. Common post-injury manifestations include impaired balance, dizziness, gait instability, reduced coordination, and decreased confidence in movement performance (Dang et al., 2017; Row et al., 2019; Fulk et al., 2024). These limitations

may substantially reduce students' participation in academic and social life and require new inclusive support strategies.

In this context, inclusive physical education should be considered not only as a curricular discipline, but also as an adaptive educational environment capable of supporting rehabilitation, functional recovery, and social reintegration. Previous studies have shown that physical education possesses considerable rehabilitative potential because structured movement tasks may improve postural control, restore coordination patterns, and increase functional independence in persons with disabilities (Pellerin, Wilson, & Haegele, 2022; Lieberman, Houston-Wilson, & Grenier, 2024; Blavt, & Herasymenko, 2024).

However, conventional rehabilitation-oriented exercise programs often face a persistent problem of low adherence

© Blavt, O., Iedynak, G., & Bezhrebelyny, Y., 2026.

caused by monotony, anxiety, and insufficient motivational support. This challenge becomes particularly relevant in university students who must sustain long-term participation while simultaneously adapting to academic demands. Therefore, the search for instructional approaches that combine therapeutic value with stable motivation remains important.

One promising solution is gamification. Gamification refers to the use of game mechanics such as points, levels, challenges, rewards, and immediate feedback in non-game contexts. In educational settings, gamification has been associated with higher motivation, stronger task engagement, and improved persistence in learning activities (Ferriz-Valero et al., 2020; Fernandez-Rio et al., 2020; Arufe-Giráldez et al., 2022). In physical education, gamification may transform repetitive rehabilitation exercises into meaningful and goal-directed activity while maintaining learner interest (Hsia et al., 2025; Jadán-Guerrero et al., 2023).

From the perspective of learning theory, gamified rehabilitation may be interpreted as an adaptive learning model in which physical tasks are progressively adjusted according to learner performance and current functional state. This creates a dynamic cycle of action, feedback, correction, and achievement. Such an approach appears especially relevant for students with blast TBI, whose recovery requires gradual progression, individualized pacing, and sustained motivation.

Despite growing interest in inclusive education and digital motivational strategies, studies examining gamified physical education programs specifically for university students with blast traumatic brain injury remain limited (Sotos-Martínez et al., 2024; Youness, Ouhir, & Lotfi, 2026). This creates both scientific and practical need to evaluate effective intervention models for this population.

The purpose of this study was to determine the effectiveness of a gamified inclusive physical education program as an adaptive rehabilitation model for university students with blast traumatic brain injury.

Material and methods

Research methods

The study was designed using an integrated methodological approach that combined theoretical analysis with empirical intervention testing. The research included two interconnected stages: conceptual development and experimental verification: theoretical and empirical.

At the theoretical stage, relevant literature on inclusive physical education, rehabilitation after traumatic brain injury, and gamification in educational settings was reviewed to develop the conceptual framework of the intervention.

The empirical stage involved evaluation of the proposed program through a controlled educational intervention. Participants were informed about the aims and procedures of the study before enrollment and provided voluntary consent to participate correctness of the pedagogical process.

Functional tests were selected according to feasibility, low equipment requirements, short administration time, and established practical relevance. Based on these criteria, the Lower

Quarter Y-Balance Test (LQYBT) and the Figure-of-8 Walk Test (F8W) were used. The F8W was selected as an ecologically valid measure of walking performance involving both linear and curved movement trajectories (Triolo et al., 2025).

The test procedure. The LQYBT has the student stand on one leg while reaching out in 3 different directions with the other lower extremity (Fig. 1). They are anterior, posteromedial and posterolateral. The maximal reach is measured by reading the distance at the edge of the reach indicator closest to the subject to the nearest half centimeter. The limb being tested is the stance limb (Physiopedia: Y Balance Test). The total indicator (composite) was determined by the value of the three directions.

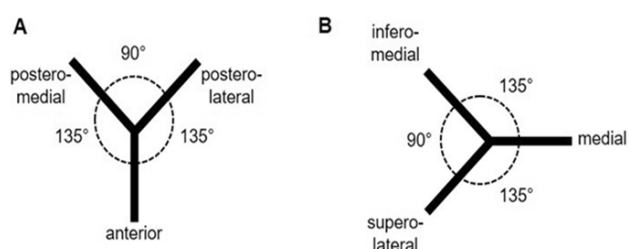


Fig. 1. Scheme of the LQYBT (Schwartz, Beurskens, & Muehlbauer, 2020)

The F8WT uses a path where the participant is asked to walk a figure of eight shape around two cones (Fig. 2.). Scores are recorded in three areas: speed (time for completion), number of steps taken and pace (Physiopedia: Figure of 8 Walk Test).

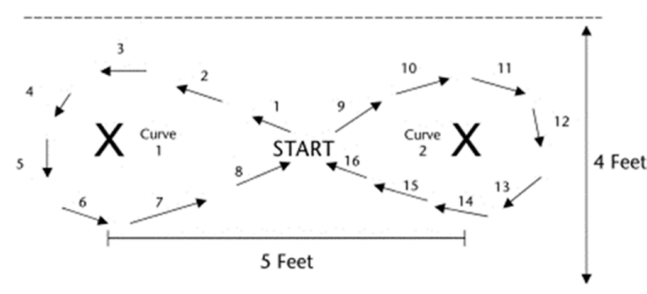


Fig. 2. Scheme of the Figure-of-8 Walk (Hess et al., 2010)

The platform «Fitocracy» was an online game and social network that aims to use gamification to help users improve their fitness (Adriane, 2011).

Study participants

Participants were twenty-eight first-year male university students aged 18 to 23 years with mild blast traumatic brain injury and mild functional impairment. The participants were recruited from Lviv Polytechnic National University and Kamianets-Podilskyi National Ivan Ohiienko University.

All participants were informed about the study procedures and provided written voluntary consent prior to participation. Inclusion criteria included mild blast traumatic brain injury without severe comorbid pathological conditions.

Medical clearance for participation in physical activity was confirmed for all participants prior to the intervention.

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant international standards for research involving human participants.

Research organization

To implement the study, a total of twenty-eight students were allocated into two groups: control group (CG, $n = 14$) and experimental group (EG, $n = 14$). The independent variable was the content and structure of the inclusive physical education program. The control group followed the standard inclusive physical education curriculum. The experimental group participated in a vestibular rehabilitation program integrated with gamification elements.

Based on the results of the test control of the students of the studied sample who completed the course in full, the conclusions of the study were substantiated. The testing procedure did not differ from the generally accepted one, the tests were performed in the gym. Outcome assessments were conducted at baseline (September) and after completion of the intervention (May). The intervention lasted two academic semesters. All tests were administered under standardized gymnasium conditions.

Statistical analysis

Quantitative data were analyzed using SPSS Version 21. Descriptive statistics included means, standard errors, standard deviations, minimum and maximum values, and coefficients of variation. Distribution normality was examined using the Shapiro-Wilk test. Between-group baseline comparisons were performed using Student's t-test. Statistical significance was set at $p < .05$.

Results

When forming the key provisions of the inclusive PE program, we were primarily guided by the fact that the key goals in blast TBI are to improve balance and coordination (Eapen, & Cifu, 2018). The developed program is based on vestibular rehabilitation with elements of gamification. Therefore, the classical principles of vestibular rehabilitation were combined with motivational game mechanics: points, levels, challenges, and feedback.

Vestibular rehabilitation consists of repeated performance of certain actions or movements that cause mild dizziness or instability (Tan, & Stern, 2026). This regular training can allow the brain and body to adapt to a chronic problem of dizziness or recover from an acute vestibular injury.

Gamification in education is understood as the introduction of games, game techniques and game practices for educational purposes. A distinctive feature of gamification is that one exercise works at several levels at once: motor, neural and behavioral (Fernandez-Rio et al., 2020). In fact, this combination provides a rapid and stable impact.

The main application of gamification is to increase the effectiveness of the educational process. This approach turns learning into an exciting process, offering immediate feedback and a sense of success.

The goal of the inclusive PE program for students with disabilities due to blast TBI is defined as: restoring balance function, reducing dizziness, improving coordination and stability, and increasing motivation through the game process.

When selecting the means of implementing the program, it was taken into account that blast TBI often gives a combination of vestibular, cognitive and sensory disorders. Therefore, special attention was paid not only to the content of vestibular rehabilitation tools but also to the control of load and fatigue.

The content of the program used short complexes of simple exercises: vestibular gymnastics, balance exercises, coordination exercises, including with objects, and proprioceptive exercises. The duration of the complexes is 5–15 min with pauses. At the same time, sensory overload from the effects of light, sound, and movement was minimized. Individualization of the load was implemented depending on the symptoms. They gradually moved from static exercises to dynamic and complex coordination tasks.

Gamification was subordinated to the goals of vestibular rehabilitation. In the case when the game overloaded or provoked symptoms, it was simplified or removed. The so-called «calm rehabilitation game» was used at a calm pace without elements of bright gamification. Flickering, loud sounds, and overloaded interfaces were avoided.

The app used “Fitocracy”, has a large amount of content, such as workout guides, nutrition tips, etc. It provides the opportunity for students to form groups and compete with each other.

New, more complex exercises became available only after successfully completing the basic level. The level of complexity was gradually increased, new exercises were discovered, and sensory load was increased based on test control data. Effective gamification in rehabilitation is: maximum therapeutic benefit, minimum sensory overload and stable motivation.

The effectiveness of the developed program was tested by implementing the second part of the experimental study. Given that an objective and unified assessment of the functional state of the body is an essential component of rehabilitation measures. Test control was used as the basis for personalized corrections of the means of influence.

At the initial stage of the study, a comparative analysis of indicators in the EG and CG was conducted (Table 1). The absence of statistically significant differences between the groups was established, which is confirmed by the Student's t-test values of $p > 0.05$. At the end – the result was completely different.

Preliminary analysis using the Shapiro-Wilk W-test indicated that the distributions of the studied variables did not substantially deviate from normality ($W = 0.79–0.95$). Therefore, parametric procedures were considered appropriate. Baseline comparisons using Student's t-test revealed no statistically significant differences between the experimental and control groups ($p > .05$), indicating initial comparability of the groups.

Post-intervention analysis demonstrated positive changes across all measured indicators in both groups; however, improvements were substantially greater in the experimental group (Table 2) than in the control group (Table 3). Mean relative gains in the experimental group ranged from 15.3% to 22.1%, whereas corresponding changes in the control group did not exceed 5.7%. Variability in the experimental group also decreased after the intervention, as reflected by lower coefficients of variation, suggesting more stable performance in balance and coordination tasks in EG participants.

Table 1. Test results before the start of the experiment (n = 28)

Component indicator		Basic statistics							
		X	m	S	Min	Max	V	D	p
Anterior	CG	55.01	0.53	6.22	41.88	65.14	14.55	0.923	0.005432
	EG	58.41	0.31	6.18	40.01	66.02	14.99	0.929	0.005421
Posteromedial	CG	83.01	1.65	5.13	65.11	88.29	13.91	0.888	0.003301
	EG	86.32	1.11	6.13	74.16	95.2	8.03	0.932	0.007201
Posterolateral	CG	81.6	1.51	6.15	68.06	95.14	8.03	0.926	0.005321
	EG	80.2	0.95	5.12	64.18	90.44	6.38	0.864	0.002109
Composite	CG	219.08	7.89	15.08	164.0	231.03	23.3	0.793	0.005641
	EG	224.93	8.57	14.84	248.15	210.2	19.79	0.815	0.004391
F8W Time (sec)	CG	9.34	0.223	1.94	7.94	11.74	12.81	0.936	0.006132
	EG	9.11	0.76	0.14	7.55	11.62	8.33	0.942	0.005221
F8W Steps (number)	CG	15.18	0.28	1.52	10.62	19.03	10.01	0.882	0.001534
	EG	14.88	0.26	1.49	12.02	16.12	11.13	0.956	0.000168
F8W Rate (number /sec)	CG	1.85	0.051	0.16	1.71	1.98	10.22	0.914	0.000134
	EG	1.93	0.07	0.19	1.82	2.03	12.01	0.872	0.000391

Table 2. Results of test control at the end of the experimental study EG (n = 14)

Statistical parameters gait	Test tasks and measurement results								
	at the beginning of the experiment				after of the experiment				effect%
	X	m	S	V	X	m	S	V	
Anterior	58.4	0.31	6.18	14.99	67.33	0.29	5.15	6.1	15.3
Posteromedial	86.32	1.11	6.13	8.03	102.81	1.03	5.71	8.3	19.1
Posterolateral	80.2	0.95	5.12	6.38	94.07	0.91	5.22	6.5	17.3
Composite	224.93	8.57	14.84	19.79	265.19	7.22	13.14	8.2	17.9
F8W Time (sec)	9.1	0.76	0.14	8.33	7.30	0.61	0.46	7.9	19.8
F8W Steps (number)	14.99	0.26	1.49	11.13	11.68	0.21	1.43	7.3	22.1
F8W Rate (number /sec)	1.93	0.07	0.19	12.01	2.34	0.06	0.22	3.8	21.3

*The differences in the results at the beginning and after of the experiment are significant (p<0.05–0.001)

Table 3. Results of test control at the end of the experimental study CG (n = 14)

Statistical parameters gait	Test tasks and measurement results								
	at the beginning of the experiment				after of the experiment				effect%
	X	m	S	V	X	m	S	V	
Anterior	55.01	0.53	6.22	14.55	57.05	0.31	6.01	10.3	3.7
Posteromedial	83.01	1.65	5.13	13.91	87.33	0.17	1.71	12.1	5.2
Posterolateral	81.6	1.51	6.15	8.03	85.07	1.31	6.28	9.9	5.1
Composite	219.08	7.89	15.08	23.3	229.81	8.03	14.44	13.4	4.9
F8W Time (sec)	9.34	0.223	1.94	12.81	8.81	0.33	1.66	12.6	5.7
F8W Steps (number)	15.18	0.28	1.52	19.03	14.50	0.31	1.53	13.4	4.5
F8W Rate (number /sec)	1.85	0.51	0.16	10.22	1.94	0.65	0.21	12.6	4.9

*The differences in the results at the beginning and after of the experiment are significant (p<0.05–0.001)

Reductions in standard errors and standard deviations after the intervention suggest a more consistent level of functional performance among participants in the experimental group. Marked improvements in Figure-of-8 Walk outcomes may reflect enhanced movement efficiency, dynamic control, and task confidence developed during the program improve vestibular response.

The largest improvement was observed in the posteromedial reach direction (19.1%), which may indicate

better proprioceptive regulation and lower-limb stabilization capacity. In addition, faster completion time (19.8%) and fewer steps (22.1%) in the Figure-of-8 Walk Test suggest more efficient gait organization and improved locomotor control with optimal step length.

Although the control group also demonstrated modest positive changes, the magnitude of improvement was consistently smaller than that observed in the experimental group across all indicators.

Discussion

The findings indicate that the gamified inclusive physical education program was more effective than the standard format in improving balance, coordination, and walking performance in university students with blast traumatic brain injury. These results support the view that physical education may function not only as an academic discipline, but also as a structured rehabilitation environment for students with disability-related functional limitations.

The observed improvements in dynamic balance suggest positive changes in postural control, vestibular adaptation, and proprioceptive regulation. Balance impairment is one of the most common persistent consequences of traumatic brain injury and substantially affects functional independence, confidence in movement, and participation in daily activities (Dang et al., 2017; Row et al., 2019; Fulk et al., 2024). Previous studies have shown that structured movement programs may improve stability and restore impaired motor patterns in persons with disabilities (Pellerin, Wilson, & Haegele, 2022; Lieberman, Houston-Wilson, & Grenier, 2024). The present results extend these findings to the context of university students with blast traumatic brain injury.

Marked positive changes in walking efficiency and coordination may be explained by the progressive and task-oriented character of the intervention. Repeated practice with gradual increases in difficulty is considered one of the key mechanisms of motor recovery after neurological impairment. Continuous correction during movement execution also contributes to sensorimotor relearning and more stable movement control (Blavt & Herasymenko, 2024). These principles were incorporated into the design of the experimental program and may explain its superiority over the standard format.

An additional explanation for the observed effects may be the motivational influence of gamification. Previous research has associated gamified learning environments with higher engagement, stronger persistence, and more positive attitudes toward regular participation (Ferriz-Valero et al., 2020; Fernandez-Rio et al., 2020; Arufe-Giráldez et al., 2022). In physical education, game mechanics such as progression levels, challenges, rewards, and immediate feedback may transform repetitive rehabilitation tasks into meaningful goal-directed activity (Hsia et al., 2025; Jadán-Guerrero et al., 2023). This mechanism may be particularly important for students recovering from blast traumatic brain injury, for whom monotony, anxiety, and reduced confidence may limit adherence.

The results may also indicate broader psychoeducational benefits of the program. Increased confidence in movement performance, successful task completion, and visible progress may positively influence self-efficacy and readiness for participation in academic and social life. Although these variables were not directly measured, such effects are theoretically consistent with adaptive learning models based on feedback, progressive challenge, and achievable goals.

Another important implication concerns the role of personalization. Recovery after traumatic brain injury often requires individual pacing, continuous monitoring, and adjustment of task difficulty according to current functional capacity. Gamified systems are well suited to this requirement because they allow flexible progression and immediate response to learner performance. Therefore, gamification in

this context should be considered not merely a motivational addition, but also a practical tool for individualized rehabilitation management.

The study also contributes to the still limited evidence base concerning gamified rehabilitation approaches for persons with traumatic brain injury. Previous authors have emphasized the need for innovative strategies that reduce monotony and improve adherence during recovery processes (Välimäki et al., 2017; Sgubin, Deodato, & Murena, 2023). The present findings suggest that inclusive university physical education may provide an effective setting for implementing such strategies.

The practical relevance of the results is especially high for contemporary Ukrainian higher education. Under wartime conditions, universities increasingly face the need to support students whose disabilities are associated with blast injuries. Therefore, inclusive physical education should move beyond formal participation models and incorporate evidence-based rehabilitation approaches integrated into the educational environment. The tested program represents one feasible model combining inclusion, functional recovery, and sustained participation.

The control group also demonstrated modest positive changes, which may reflect the general benefits of regular physical activity. However, the substantially smaller magnitude of improvement indicates that standard physical education formats alone may be insufficient for students with blast traumatic brain injury who require targeted and adaptive support.

Limitations

This study has several limitations. The sample size was relatively small and included only male first-year students, which limits the generalizability of the findings. The intervention was conducted in two universities only, and institutional differences were not separately analyzed. Long-term retention of functional gains after completion of the program was not examined. In addition, psychological outcomes such as motivation, anxiety, self-efficacy, and quality of life were not directly measured. Future studies should include more diverse samples, broader institutional settings, psychological indicators, and follow-up assessments after program completion.

Conclusions

The gamified inclusive physical education program showed superior outcomes compared with the standard format in improving balance, coordination, and walking performance in university students with blast traumatic brain injury. Functional gains in the experimental group substantially exceeded those observed in the control group, indicating the added value of a structured intervention combining rehabilitation tasks with motivational game mechanics.

The integration of vestibular rehabilitation exercises with progression-based challenges and immediate feedback likely enhanced participant engagement, adherence, and confidence in movement performance. These findings support the interpretation of post-injury recovery within physical education as an adaptive learning process based on repeated practice, performance feedback, and gradual task progression.

The practical relevance of the study is especially high for contemporary Ukrainian higher education, where wartime

conditions have increased the need to support students with disability related to blast injuries. In this context, inclusive physical education should extend beyond formal participation models and incorporate evidence-based strategies that combine educational inclusion with functional rehabilitation.

The results suggest that gamified inclusive physical education may serve as a feasible university-based model for addressing balance and coordination limitations in students with blast traumatic brain injury. Future research should examine long-term effects, psychological outcomes, and the applicability of this approach across broader student populations and institutional settings.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

AI Transparency Statement

The author declares that no generative AI or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript.

Funding statement

This research received no external funding.

Clarified Ethics Approval

This study was approved by the Research Ethics Committee Міжнародного Каміанець-Подільського Національного Університету Івана Огієнка (KPNУ 2025-014) before the start of the study.

Conflicts of interest

No conflicts of interest exist.

References

- Klos, L. Y., Blavt, O. Z., & Kovalchuk, O. P. (2024). Implementation of complex rehabilitation of disabled veterans of the Russian-Ukrainian war in institutions of higher education. *Rehabilitation and Recreation*, 18(3), 10–22. <https://doi.org/10.32782/2522-1795.2024.18.3.1>
- Dang, B., Chen, W., He, W., & Chen, G. (2017). Rehabilitation treatment and progress of traumatic brain injury dysfunction. *Neural Plasticity*, 2017, Article 1582182. <https://doi.org/10.1155/2017/1582182>
- Row, J., Chan, L., Damiano, D., Shenouda, C., Collins, J., & Zampieri, C. (2019). Balance assessment in traumatic brain injury: A comparison of the sensory organization and limits of stability tests. *Journal of Neurotrauma*, 36(16), 2435–2442. <https://doi.org/10.1089/neu.2018.5755>
- Fulk, G. D., Nirider, C., Williams, G., & DeBlois, A. (2024). *Traumatic brain injury*. In G. D. Fulk, & K. K. Chui (Eds.), *O'Sullivan & Schmitz's physical rehabilitation* (8th ed.). F. A. Davis Company.
- Pellerin, S., Wilson, W. J., & Haegele, J. A. (2022). The experiences of students with disabilities in self-contained physical education. *Sport, Education and Society*, 27(1), 14–26. <https://doi.org/10.1080/13573322.2020.1817732>
- Lieberman, L. J., Houston-Wilson, C., & Grenier, M. (2024). *Strategies for inclusion: Physical education for everyone*. Human Kinetics.
- Blavt, O., & Herasymenko, O. (2024). Inclusive physical education of students with disabilities due to war injuries: Restoration of lower extremity functions. *Journal of Learning Theory and Methodology*, 5(1), 5–12. <https://doi.org/10.17309/jltm.2024.5.1.01>
- Ferriz-Valero, A., Østerlie, O., Martínez, S. G., & García-Jaén, M. (2020). Gamification in physical education: Evaluation of its impact on motivation and academic performance within higher education. *International Journal of Environmental Research and Public Health*, 17(12), 4465. <https://doi.org/10.3390/ijerph17124465>
- Fernandez-Rio, J., de las Heras, E., González, T., Trillo, V., & Palomares, J. (2020). Gamification and physical education: Viability and preliminary views from students and teachers. *Physical Education and Sport Pedagogy*, 25(5), 509–524. <https://doi.org/10.1080/17408989.2020.1743253>
- Arufe-Giráldez, V., Sanmiguel-Rodríguez, A., Ramos-Álvarez, O., & Navarro-Patón, R. (2022). Gamification in physical education: A systematic review. *Education Sciences*, 12(8), 540. <https://doi.org/10.3390/educsci12080540>
- Hsia, L. H., Lin, Y. N., Lin, C. H., & Hwang, G. J. (2025). Effectiveness of gamified intelligent tutoring in physical education through the lens of self-determination theory. *Computers & Education*, 227, Article 105212. <https://doi.org/10.1016/j.compedu.2024.105212>
- Jadán-Guerrero, J., Avilés-Castillo, F., Buele, J., & Palacios-Navarro, G. (2023). *Gamification in inclusive education for children with disabilities: Global trends and approaches—A bibliometric review*. In O. Gervasi et al. (Eds.), *Computational Science and Its Applications – ICCSA 2023 Workshops* (pp. 461–477). Springer. https://doi.org/10.1007/978-3-031-37105-9_31
- Sotos-Martínez, V. J., Tortosa-Martínez, J., Baena-Morales, S., & Ferriz-Valero, A. (2024). It's game time: Improving basic psychological needs and promoting positive behaviours through gamification in physical education. *Retos*, 59, 760–768. <https://doi.org/10.47197/retos.v59.103867>
- Youness, M., Ouhir, S., & Lotfi, S. (2026). The effects of digital technologies on physical education outcomes: A systematic review and meta-analysis. *Physical Education Theory and Methodology*, 26(2), 230–250. <https://doi.org/10.17309/tmfv.2026.2.02>
- Triolo, G., Lombardo, R., Ivaldi, D., Quartarone, A., & Lo Buono, V. (2025). An Overview About Figure-of-Eight Walk Test in Neurological Disorders: A Scoping Review. *Neurology International*, 17(7), 112. <https://doi.org/10.3390/neurolint17070112>
- Schwartz, G., Beurskens, R., & Muehlbauer, T. (2020). Discriminative validity of the lower and upper quarter Y balance test performance: a comparison between healthy trained and untrained youth. *BMC Sports Sci Med Rehabil*, 12, 73. <https://doi.org/10.1186/s13102-020-00220-w>
- Hess, R.J., Brach, J.S., Piva, S.R., & VanSwearingen, J.M. (2010). Walking skill can be assessed in older adults: validity of the Figure-of-8 Walk Test. *Phys Ther*, 90(1), 89–99. <https://doi.org/10.2522/ptj.20080121>
- Adrienne, J. (2011). *The Fitocrats: How Two Nerds Turned an Addiction to Videogames into an Addiction to Fitness*. The New York Observer. Available from: <https://observer.com/business/>

Tan, J.C., & Stern, M. (2026). *Tan's Practical Manual of Physical Medicine and Rehabilitation: 3rd Edition*. Amsterdam: Elsevier.

Välämäki, M., Mishina, K., Kaakinen, J. K., Holm, S. K., Vahlo, J., Kirjonen, M., Pekurinen, V., Tenovuori, O., Korkeila, J., Hämäläinen, H., Sarajuuri, J., Rantanen, P., Orenius, T., & Koponen, A. (2018). Digital gaming for improving the functioning of people with traumatic brain injury:

Randomized clinical feasibility study. *Journal of Medical Internet Research*, 20(3), e77. <https://doi.org/10.2196/jmir.7618>

Sgubin, G., Deodato, M., & Murena, L. (2023). Gamification in rehabilitation: The role of subjective experience in a multisensory learning context—A narrative review. *Gestalt Theory*, 45(1–2), 121–137. <https://doi.org/10.2478/gth-2023-0012>

Гейміфіковане інклюзивне фізичне виховання як адаптивна реабілітаційна модель для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою

Оксана Блавт^{1ABD}, Геннадій Єдинак^{2BCDE}, Ян Безгребельний^{1BCD}

¹Національний університет «Львівська політехніка»

²Кам'янець-Подільський національний університет імені Івана Огієнка

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 12 с., 3 табл., 2 рис., 21 джерело.

Актуальність. Триваюча війна в Україні призвела до зростання кількості студентів закладів вищої освіти, які мають інвалідність, спричинену вибуховою черепно-мозковою травмою (ЧМТ). Ця ситуація зумовлює нагальну потребу в моделях інклюзивного фізичного виховання, що поєднують реабілітаційні завдання з ефективними мотиваційними стратегіями. Гейміфікація може сприяти підвищенню участі, прихильності до занять та функціональному відновленню в умовах адаптивного освітнього середовища.

Мета дослідження. Визначити ефективність програми гейміфікованого інклюзивного фізичного виховання як адаптивної реабілітаційної моделі для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою.

Матеріали і методи. У дослідженні взяли участь 28 студентів першого курсу чоловічої статі віком 18–23 років із легкою вибуховою ЧМТ та помірними функціональними порушеннями. Учасників було розподілено на контрольну групу (n = 14) та експериментальну групу (n = 14). Контрольна група навчалася за стандартною програмою інклюзивного фізичного виховання, тоді як експериментальна група виконувала програму вестибулярної реабілітації, інтегровану з елементами гейміфікації. Тривалість втручання становила два академічні семестри. Функціональні зміни оцінювали за допомогою тесту Lower Quarter Y-Balance Test та тесту Figure-of-8 Walk Test. Дані опрацьовували методами описової статистики та t-критерію Стьюдента.

Результати. На початковому етапі статистично значущих відмінностей між групами не виявлено (p > .05). Після завершення втручання експериментальна група продемонструвала суттєво вищі покращення порівняно з контрольною групою за всіма показниками. Приріст результатів в експериментальній групі становив від 15,3% до 22,1%, тоді як зміни в контрольній групі не перевищували 5,7%. Найбільше ефекти зафіксовано щодо ефективності ходьби, контролю рівноваги та координаційних здібностей.

Висновки. Гейміфіковане інклюзивне фізичне виховання може розглядатися як ефективна адаптивна реабілітаційна модель для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою. Інтеграція структурованих фізичних вправ із мотиваційними ігровими механіками сприяла покращенню функціональних показників, залученості до занять і впевненості у руховій діяльності. Отримані результати підтверджують доцільність використання гейміфікації в інклюзивному фізичному вихованні закладів вищої освіти в умовах зростання потреб у реабілітації.

Ключові слова: інклюзивне фізичне виховання, гейміфікація, черепно-мозкова травма, адаптивне навчання, реабілітація, студенти закладів вищої освіти, рівновага, координація.

Information about the Authors:

Blavt, Oksana: oksanablavt@ukr.net; <https://orcid.org/0000-0001-5526-9339>; Department of PE, Lviv Polytechnic National University, Bandera St, 12, Lviv, 79013, Ukraine.

Iedynak, Gennadii: yedynak.g.a@gmail.com; <https://orcid.org/0000-0002-6865-0099>; Department of Theory and Methods of PE, Kamianets-Podilskyi Ivan Ohienko National University, Ohienko St, 62, Kamianets-Podilskyi, 32300, Ukraine.

Bezhrebelyny, Yan: yan.bezhrebelyny@gmail.com; <https://orcid.org/0009-0000-9750-8414>; Department of Pedagogics and Innovative Education, Lviv Polytechnic National University, Bandera St., 12, Lviv, 79013, Ukraine.

Cite this article as: Blavt, O., Iedynak, G., & Bezhrebelyny, Y. (2026). Gamified Inclusive Physical Education as an Adaptive Rehabilitation Model for University Students with Blast Traumatic Brain Injury. *Journal of Learning Theory and Methodology*, 7(1), 49–55. <https://doi.org/10.17309/jltm.2026.7.1.05>

Received: 27.03.2026. Accepted: 22.04.2026. Published: 30.04.2026

This work is licensed under a Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0>)

ISSN 2708-7581 (Online)
ISSN-L 2708-7573

JLTM

Journal of Learning Theory and Methodology

Scientific journal

April 2026

Volume 7

Number 1

Відповідальний за випуск	О. М. Худолій
Комп'ютерна верстка	М. О. Худолій
Коректор	Є. Б. Бланк

Зареєстровано в Національній раді України з питань телебачення і мовлення:
рішення No 1751 від 23.05.2024 р., протокол No 16, оприлюднено 23 травня 2024 р., ідентифікатор медіа – R40-04690

<https://webportal.nrada.gov.ua/wp-content/uploads/2024/05/R-2024-01751.pdf>

Засновник і видавець — ТОВ «ОВС».

Адреса редакції: <https://www.ltmjournal.com>. Тел.: (067) 578-40-08. E-mail: editor-in-chief@ltmjournal.com

Підписано до друку 28.04.2026. Формат 60×84 1/8. Електронне видання. Гарнітура Таймс. PDF формат.
Ум. друк. арк. 6,989. Обл.-вид. арк. 7,25. Вид. № 7(1)-2026. Зам. № 56. Тираж 300 прим. Ціна договірна.

ТОВ «ОВС» Україна, 61003 Харків, пл. Конституції, 18, к. 11.

Свідоцтво Держкомінформу України Серія ДК № 331 від 08.02.2001 р.