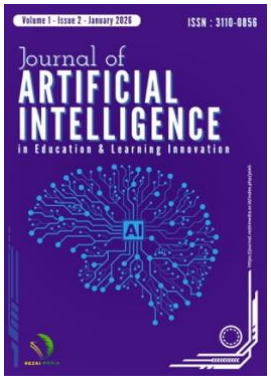

AI-driven learning in physical education: A bibliometric analysis of trends, knowledge structure, and future research directions

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A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

ABSTRACT

Background: Although research on AI-driven learning in PE has expanded rapidly, existing studies remain fragmented across disciplines, journals, and methodological approaches, limiting a comprehensive understanding of the field's development and intellectual structure.

Objectives: This study aimed to systematically map the evolution, influential contributors, intellectual structure, dominant themes, and future research directions of AI-driven learning research in physical education from a bibliometric perspective.

Methods: A quantitative bibliometric analysis was conducted using data retrieved exclusively from the Scopus database. A total of 284 eligible documents published between 2020 and early 2026 were analyzed. Descriptive statistics were applied to examine publication trends, authorship, sources, institutions, and country contributions. Network and thematic analyses were performed using VOSviewer (version 1.6.20) and the Bibliometrix package in R to identify co-authorship patterns, keyword co-occurrence networks, and thematic clusters.

Results: The results indicate a sharp growth in AI-driven learning research in physical education after 2022, with publication output increasing more than fivefold from 2020 to 2025. China emerged as the leading contributing country, accounting for nearly half of the total publications, while institutional productivity was concentrated in several Russian universities. Keyword co-occurrence analysis revealed five major thematic clusters shaping the intellectual structure of the field, integrating pedagogical frameworks, computational intelligence, institutional contexts, and physical training models. Dominant research themes centered on pedagogical design, student engagement, adaptive learning systems, and the integration of educational technology. Emerging themes included virtual reality, advanced machine learning techniques, and immersive learning environments.

Conclusions: This study provides a structured and quantitative overview of AI-driven learning research in physical education, highlighting its interdisciplinary nature and rapid expansion.

Keywords: artificial intelligence, AI-driven learning, physical education, bibliometric analysis, educational technology.

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INTRODUCTION

The rapid advancement of artificial intelligence (AI) has profoundly influenced educational practices across disciplines, including physical education (PE). AI technologies—such as machine learning, learning analytics, wearable sensors, and intelligent tutoring systems—have enabled more personalized, adaptive, and data-driven learning environments that address long-standing pedagogical challenges in PE, including learner heterogeneity, assessment complexity, and student engagement (Sargent & Casey, 2021; Yang et al., 2025). Unlike traditional teacher-centered approaches, AI-driven learning systems allow for real-time monitoring of learning processes, individualized feedback, and dynamic instructional adjustment, thereby supporting cognitive, affective, and psychomotor learning outcomes in movement-based education (Zhang, 2024).

In recent years, the integration of AI into PE has expanded beyond performance monitoring toward broader pedagogical applications, such as curriculum design, motor skill development, physical activity promotion, and motivation enhancement. Empirical studies suggest that AI-supported instructional models—particularly those incorporating learning analytics, gamification, and immersive technologies—can improve motor skill acquisition, increase physical activity levels, and foster intrinsic motivation among students (Calderón et al., 2020; Krause et al., 2020; Lee & Gao, 2020; Mokmin, 2020; Vega et al., 2020; Yang et al., 2020). These developments indicate a conceptual shift in PE research, where AI is increasingly positioned not merely as a technological tool, but as a pedagogical enabler that reshapes teaching and learning processes.

Despite the growing body of literature on AI-driven learning in physical education, existing studies remain fragmented across disciplines, publication outlets, and methodological approaches. Research outputs are distributed among journals in sport science, educational technology, and applied computational sciences, making it challenging to obtain a comprehensive understanding of the field's development, key contributors, and intellectual foundations (Sargent & Lynch, 2021; Zhang, 2025). Moreover, while several reviews and empirical studies have examined specific AI applications in PE, there is still limited systematic evidence mapping the overall research landscape, thematic evolution, and emerging directions from a macro-level perspective.

Despite the increasing volume of studies on artificial intelligence applications in physical education, a critical gap remains in the literature at the macro-analytical level. Existing research has predominantly focused on specific AI technologies (e.g., wearable sensors, learning analytics, virtual reality, augmented reality) or isolated pedagogical interventions, often through empirical or narrative review approaches (Chang et al., 2020; Deng, Bi, & Li, 2024; Lindberg, Seo, & Laine, 2016; Meng, 2021; Pratama, Scucipto, & Hanief, 2022). While several reviews have discussed the pedagogical potential or instructional implications of AI in physical education, they do not systematically map the intellectual structure of the field, identify dominant and emerging research themes, or examine collaboration patterns among authors, institutions, and countries over time. Consequently, there remains a lack of comprehensive bibliometric synthesis that captures the evolution of AI-driven learning research in physical education, the structure of knowledge, and the direction of future research efforts.

To the best of the authors' knowledge, this study represents one of the first comprehensive bibliometric analyses to systematically examine the evolution, intellectual structure, and thematic development of AI-driven learning research in physical education, utilizing large-scale Scopus data. By adopting a bibliometric approach, this study transcends technology-specific or intervention-focused reviews, offering a macro-level perspective on research trends, knowledge networks, and future directions in this rapidly evolving interdisciplinary field.

Bibliometric analysis offers a rigorous and objective approach to addressing these gaps by quantitatively examining publication patterns, citation structures, and keyword relationships within a research field. By applying bibliometric techniques, it is possible to identify influential authors, journals, institutions, and countries, as well as to reveal the intellectual structure and dominant research themes that shape AI-driven learning in physical education. Such an approach is particularly valuable for an interdisciplinary and rapidly evolving domain, where conceptual boundaries and research priorities are still being formed (Xu et al., 2022).

Accordingly, this study aims to provide a comprehensive bibliometric analysis of AI-driven learning research in physical education to map its development, structure, and future directions. To achieve this aim, the study addresses the following research questions:

RQ1: How has AI-driven learning research in physical education evolved over time?

RQ2: Who are the most influential authors, journals, institutions, and countries?

RQ3: What is the intellectual structure of this research field?

RQ4: What are the dominant and emerging research themes?

RQ5: What future research directions can be identified?

METHODS

Study Design and Data Source

This study employed a bibliometric analysis using a quantitative research approach to systematically map the development, structure, and evolution of scientific knowledge related to AI-driven learning in physical education. Bibliometric methods enable the objective analysis of large volumes of academic literature by examining publication patterns, citation structures, and thematic relationships within a research field. This approach is particularly suitable for identifying research trends, influential contributors, and emerging themes in interdisciplinary domains such as artificial intelligence in education.

The bibliographic data were retrieved exclusively from the Scopus database, which was selected due to several key considerations. First, Scopus provides broad multidisciplinary coverage, encompassing education, computer science, and sport sciences, which are all relevant to AI-driven learning in physical education. Second, Scopus offers high-quality and standardized metadata, including author information, affiliations, keywords, and citation data, which are essential for reliable bibliometric analysis. Finally, Scopus is widely recognized and accepted in bibliometric and scientometric studies, ensuring comparability with prior international research.

While Scopus was selected as the sole data source due to its broad multidisciplinary coverage and standardized metadata, this choice also has methodological implications for the scope of the analysis. Relying on a single database may result in the exclusion of relevant publications indexed exclusively in

other databases, such as Web of Science or ERIC, particularly studies published in regionally focused or non-English language journals. However, given the objectives of this study to provide a consistent and replicable macro-level mapping of AI-driven learning research in physical education, the use of a single, comprehensive database ensures data homogeneity and methodological transparency, which are essential for reliable bibliometric analysis.

Search Strategy

A systematic search strategy was developed to retrieve publications related to the application of artificial intelligence in physical education learning. The search was conducted using the TITLE-ABS-KEY field in Scopus to ensure that the core concepts were explicitly addressed. The search terms were organized into two concept groups: (1) artificial intelligence–related terms and (2) physical education–related terms. These two groups were combined using the Boolean operator "AND", while synonyms within each group were connected using "OR" to avoid ambiguity in query logic. The search query combined two main groups of keywords: (TITLE-ABS-KEY (artificial intelligence) OR TITLE-ABS-KEY (AI-driven learning) OR TITLE-ABS-KEY (educational technology) OR TITLE-ABS-KEY (digital learning) AND TITLE-ABS-KEY (physical education) OR TITLE-ABS-KEY (K–12 physical education) OR TITLE-ABS-KEY (physical education teaching)).

The full search string was applied without time restrictions and was limited to documents written in English. The complete search query is provided in the appendix to ensure transparency and reproducibility.

Inclusion Criteria:

Documents were included in the analysis if they met the following criteria:

1. Indexed in the Scopus database;
2. Written in English;
3. Classified as peer-reviewed scholarly works;
4. Published as articles, conference papers, reviews, book chapters, or conference reviews; and
5. Explicitly addressed the use of artificial intelligence or AI-related technologies in the context of physical education learning

Exclusion Criteria:

Documents were excluded from the analysis based on the following criteria:

1. Editorials, notes, letters, short communications, or non-scholarly publications;
2. Studies focusing on professional or elite sports performance without an educational or learning context; and
3. Publications applying artificial intelligence in non-pedagogical contexts, such as medical diagnostics or sports engineering without relevance to learning or teaching

Data Screening Procedure

A PRISMA-adapted flow diagram was used to document the data selection process. An initial search of the Scopus database using predefined keywords yielded 10,241 records. Subsequently, records were filtered based on document type, excluding reviews, book chapters, conference papers, editorials, and other non-article publications, resulting in the exclusion of 5,936 records. The remaining 4,305 articles were screened by title and abstract to identify studies relevant to physical education

contexts. Following this screening, 284 articles were deemed eligible and included in the final bibliometric analysis (Figure 1).

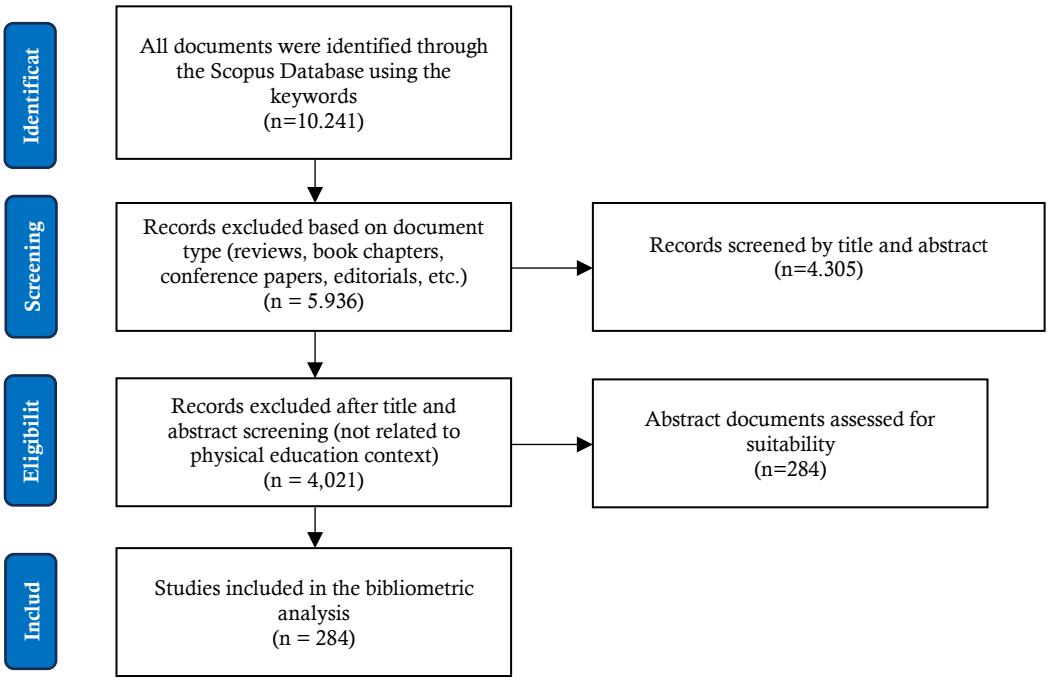

Figure 1. PRISMA-adapted flow diagram illustrating the identification, screening, eligibility, and inclusion process of studies retrieved from the Scopus database on AI-driven learning in physical education

Data Analysis

Bibliometric data analysis in this study was conducted using the Bibliometrix package in R, implemented through the Biblioshiny web interface, to ensure a comprehensive and reproducible mapping of the scientific landscape. Biblioshiny was employed to perform both descriptive and network-based bibliometric analyses, including the examination of annual scientific production, citation distributions, source and author impact indicators, and country-level contributions. In addition, network analyses were conducted to visualize co-authorship patterns, international collaboration networks, and keyword co-occurrence structures, enabling the identification of collaboration dynamics, intellectual foundations, and thematic relationships within the field. Advanced analytical techniques, such as thematic mapping and thematic evolution analysis, were further applied to explore the conceptual structure and temporal development of AI-driven learning research in physical education. The integration of descriptive statistics with network and thematic analyses provided a holistic understanding of both the structural and conceptual dimensions of the research field.

RESULTS

Publication Growth and Document Characteristics

A total of 284 documents related to AI-driven learning in physical education were included in the bibliometric analysis. The annual distribution of publications reveals a clear and accelerating growth trend over the examined period (Figure 2). Research output remained relatively limited between 2020 and 2021, with only 13 and 39 publications, respectively, indicating that the application of artificial intelligence in physical education was still at an early stage of scholarly exploration. A steady

increase is observed in 2022 (49 publications) and 2023 (41 publications), followed by a sharp rise in 2024 (69 publications). The highest number of publications was recorded in 2025 (71 documents), reflecting a substantial expansion of academic interest in AI-driven learning within physical education contexts.

The small number of publications indexed in early 2026 (n = 2) reflects partial-year indexing, as data collection was conducted in January 2026. Overall, this publication trajectory demonstrates that AI-driven learning in physical education has rapidly evolved into a prominent and contemporary research domain, driven by advances in artificial intelligence, learning analytics, and digital educational technologies.

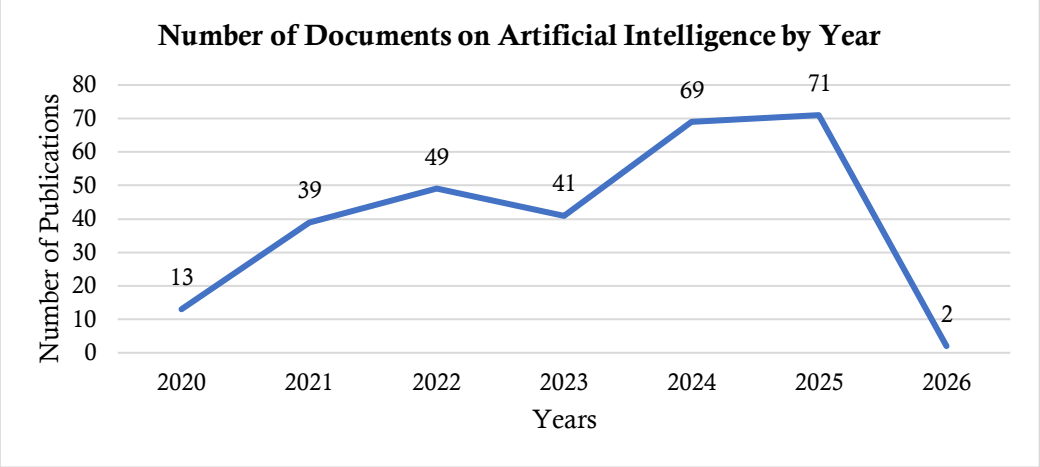

Figure 2. Annual scientific production of AI-driven learning research in physical education (2020–2026).

Most Productive Authors

As presented in Table 1 and visualized in Figure 3, the distribution of the most productive authors in AI-driven learning research in physical education reveals a relatively dispersed authorship structure. Liu, Z., emerges as the most productive author with six publications, followed by Wang, Y., with five publications. Meanwhile, several other authors, including Calderón, A., Chen, J., Sargent, J., and Zhang, L., each contributed four publications. The remaining authors within the top ten demonstrate comparable productivity levels, indicating the absence of a single dominant author in the field. This pattern suggests that research on AI-driven learning in physical education is characterized by a broad and distributed authorship base rather than being driven by a small group of highly prolific scholars. Such dispersion reflects the interdisciplinary and evolving nature of the field, where contributions arise from diverse research backgrounds and collaborative networks.

Table 1. Top 10 Most Productive Authors

No	Author's Name	Number of Documents
1	Liu, Z.	6
2	Wang, Y.	5
3	Calderon, A.	4
4	Chen, J.	4
5	Sargent, J.	4
6	Zhang, L.	4
7	Araujo, A. C.	3
8	Blavt, O.	3
9	Chen, K.	3
10	Cheng, J.	3

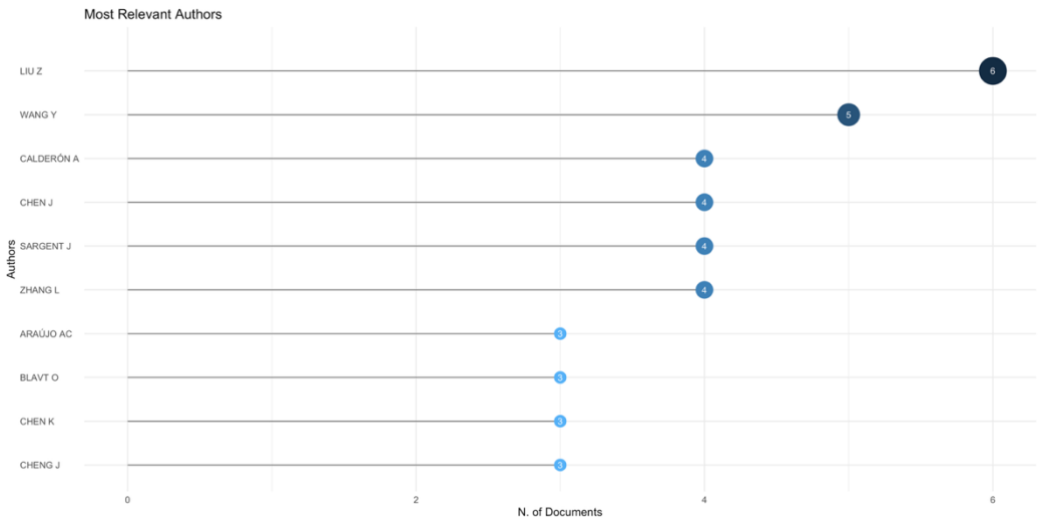

Figure 3. Top 10 Most Productive Authors

Table 2. Top 10 Source Title

No	Source Title	Number of Documents	Total Citations	h-index
1	Applied Mathematics and Nonlinear Sciences	24	32	2
2	Journal of Physical Education and Sport	13	36	4
3	Mobile Information Systems	12	177	6
4	Education and Information Technologies	10	124	6
5	Journal of Intelligent and Fuzzy Systems	8	36	3
6	Retos	8	36	3
7	Wireless Communications and Mobile Computing	7	112	4
8	Computer-Aided Design And Applications	6	11	2
9	Education Sciences	6	59	3
10	Frontiers in Sports and Active Living	6	4	2

Note: Citation indicators reported in this table represent local impact metrics calculated within the analyzed dataset and do not correspond to global journal metrics from Scopus

Leading Source Titles

Table 2 and Figure 4 present the top ten most relevant source titles contributing to AI-driven learning research in physical education, highlighting notable differences between publication productivity and citation impact. Applied Mathematics and Nonlinear Sciences emerges as the most productive source with 24 documents; however, its total citation count and h-index remain relatively modest, indicating that high publication volume does not necessarily translate into higher citation impact within the dataset. In contrast, Mobile Information Systems and Education and Information Technologies demonstrate stronger scholarly influence, as reflected by their substantially higher total citations (177 and 124, respectively) and higher h-index values (both h = 6), despite publishing fewer documents. Journals such as the Journal of Physical Education and Sport, Wireless Communications and Mobile Computing, and the Journal of Intelligent and Fuzzy Systems show balanced profiles, combining moderate productivity with consistent citation performance. Overall, these findings suggest that AI-driven learning research in physical education

is disseminated across a diverse range of disciplinary outlets, with impact distributed unevenly across sources, reflecting the interdisciplinary and still consolidating nature of the field.

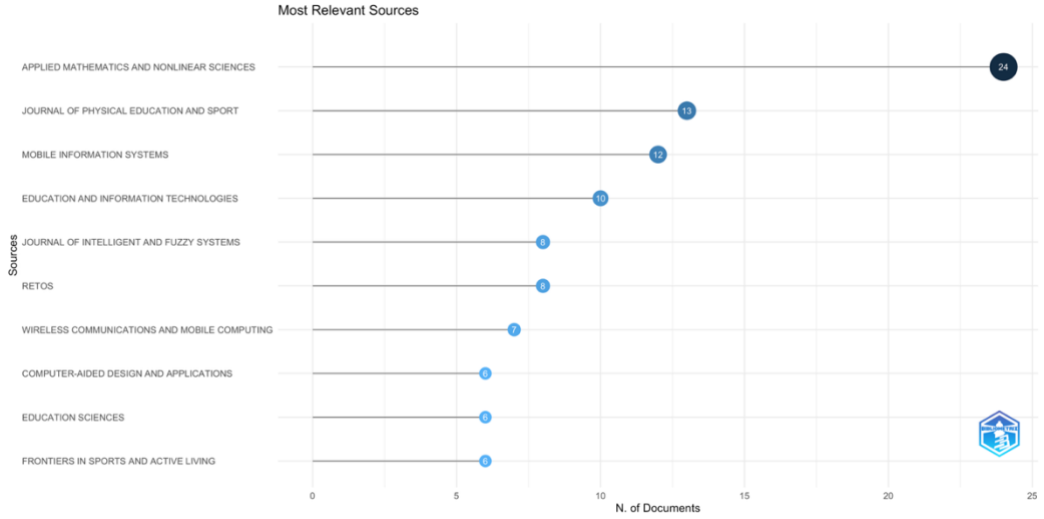

Figure 4. Top 10 Source Title

Institutional Contributions

Table 3 and Figure 5 illustrate the top ten institutional contributors to AI-driven learning research in physical education. Shandong University and Universitat d'Alacant emerge as the most productive institutions, each contributing six documents, indicating their prominent role in shaping the research output of this field. Several other institutions, including Universitas Negeri Semarang, Universitatea Spiru Haret, and the University of Limerick, demonstrate comparable levels of contribution with five publications each, reflecting a relatively distributed pattern of institutional productivity. The remaining institutions in the top ten—such as Altai State University, Chongqing University of Posts and Telecommunications, Deakin University, Immanuel Kant Baltic Federal University, and Lviv Polytechnic National University—each contribute four documents, further underscoring the absence of a single dominant institutional hub. Overall, these findings suggest that AI-driven learning research in physical education is characterized by geographically diverse institutional participation, with contributions spread across Asia, Europe, and Oceania, reinforcing the interdisciplinary and globally distributed nature of the research landscape.

Table 3. Top 10 Institutional Contributions

No	Affiliation	Number of Documents
1	Shandong University	6
2	Universitat D'alacant	6
3	Universitas Negeri Semarang	5
4	Universitatea Spiru Haret	5
5	University Of Limerick	5
6	Altai State University	4
7	Chongqing University Of Posts And Telecommunications	4
8	Deakin University	4
9	Immanuel Kant Baltic Federal University	4
10	Lviv Polytechnic National University	4

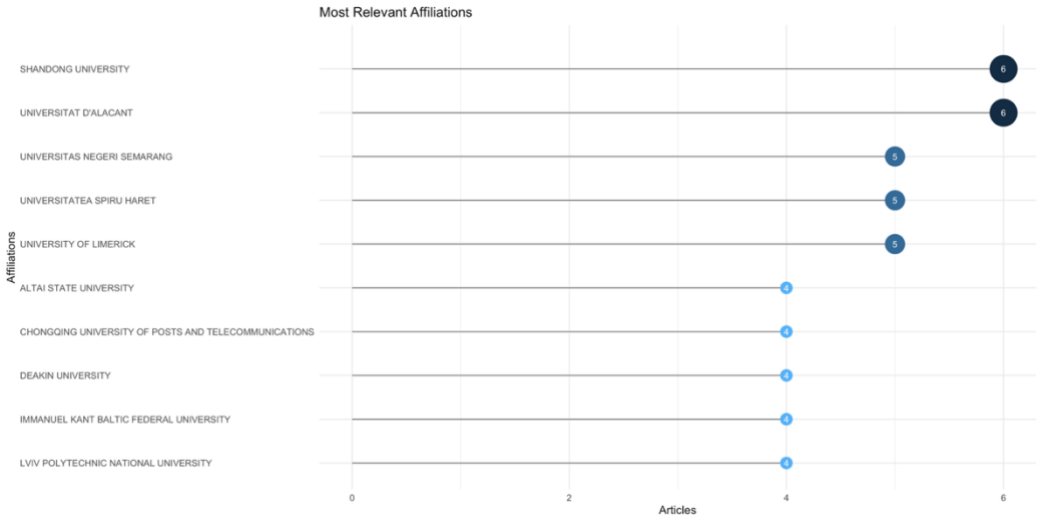

Figure 5. Affiliations' Production over Time

Table 4. Top 10 Country Contributions

No	Country	Number of Documents
1	China	233
2	Spain	37
3	Ukraine	36
4	Indonesia	35
5	United States	35
6	Kazakhstan	24
7	Philippines	21
8	United Kingdom	19
9	Malaysia	17
10	Australia	16

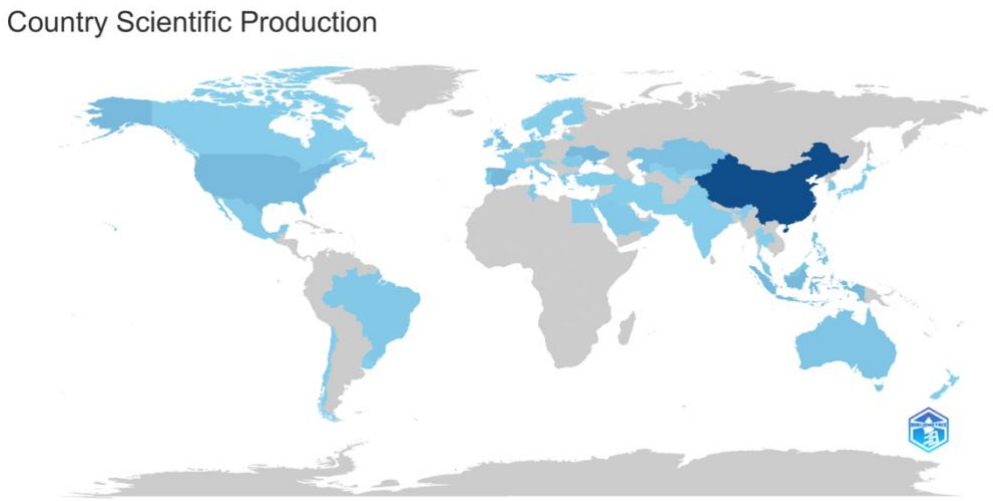

Figure 6. Top 10 Country Scientific Production

Country Contributions

Table 4 and Figure 6 present the top ten countries contributing to AI-driven learning research in physical education. China clearly dominates the field with 233 documents, accounting for a substantially larger share of publications compared to other countries. This pronounced dominance highlights China's strong national emphasis on artificial intelligence, educational technology integration, and large-scale research investment. Spain, Ukraine, Indonesia, and the United States form a secondary group of contributors, each producing between 35 and 37 documents,

indicating a more balanced but comparatively moderate level of research activity. Additional contributions from Kazakhstan, the Philippines, the United Kingdom, Malaysia, and Australia further demonstrate the global diffusion of research efforts across both developed and developing contexts. The geographic distribution visualized in Figure 6 reveals a concentration of scientific production in Asia and Europe, while also indicating emerging contributions from Southeast Asia and Oceania. Overall, these findings suggest that global research on AI-driven learning in physical education is shaped by both established research systems and emerging national agendas, reflecting differing levels of policy support, technological infrastructure, and institutional capacity across countries.

Intellectual Structure and Thematic Patterns

Network, density, and overlay visualizations generated using VOSviewer (version 1.6.20) reveal a complex and multi-layered intellectual structure within the research field of AI-driven learning in physical education (Figure 7). The keyword co-occurrence network demonstrates a highly interconnected and interdisciplinary knowledge structure, with physical education and artificial intelligence occupying central positions in the network. This centrality indicates that technological innovation and pedagogical practice are tightly integrated rather than treated as separate research domains.

As shown in Figure 7, the keyword co-occurrence analysis identifies several distinct but interrelated thematic clusters. Node size represents the frequency of keyword occurrence, while link strength reflects the intensity of co-occurrence relationships between terms, illustrating the conceptual proximity among research topics.

The red cluster, which is the most prominent and centrally positioned, is dominated by pedagogical and educational technology–oriented keywords such as physical education, education, learning, teacher, student engagement, motivation, educational technology, curriculum, and professional development. This cluster represents the core pedagogical dimension of AI-driven learning research in physical education, emphasizing instructional design, learner engagement, technology-enhanced pedagogy, and teacher-related issues. The presence of terms such as ICT, online learning, blended learning, and gamification further highlights the integration of digital learning environments into physical education teaching practices.

The blue cluster is primarily associated with computational and data-driven methodologies, featuring keywords such as machine learning, learning algorithms, data mining, decision trees, educational robots, curricula, and education teachers. This cluster reflects the technological and analytical foundations underpinning AI applications in physical education, particularly in relation to intelligent systems, algorithmic modeling, and automated decision-support tools used to enhance teaching and learning processes.

Based on Figure 7, the green cluster focuses on institutional and technological infrastructure contexts, including keywords such as colleges and universities, college physical education, artificial intelligence technology, e-learning, education computing, digital storage, and data handling. This cluster highlights the role of higher education institutions as key environments for the adoption and experimentation of AI-driven learning technologies in physical education, as well as the importance of data management and digital infrastructure.

The purple cluster is closely linked to instructional models and physical training contexts, with prominent keywords including computer-aided instruction, physical training, physical fitness, teaching model, human bodies, and optimisations. This cluster reflects research efforts aimed at integrating AI-supported instructional models with physical training and fitness outcomes, emphasizing the optimization of teaching strategies and learning effectiveness in movement-based education.

The yellow cluster represents emerging intersections between digital teaching quality and advanced technologies, encompassing keywords such as education computing, digital teaching, teaching quality, virtual reality technology, adversarial machine learning, and network technologies. Although comparatively smaller, this cluster suggests emerging and exploratory research directions, particularly related to immersive technologies and advanced machine learning approaches in physical education learning environments.

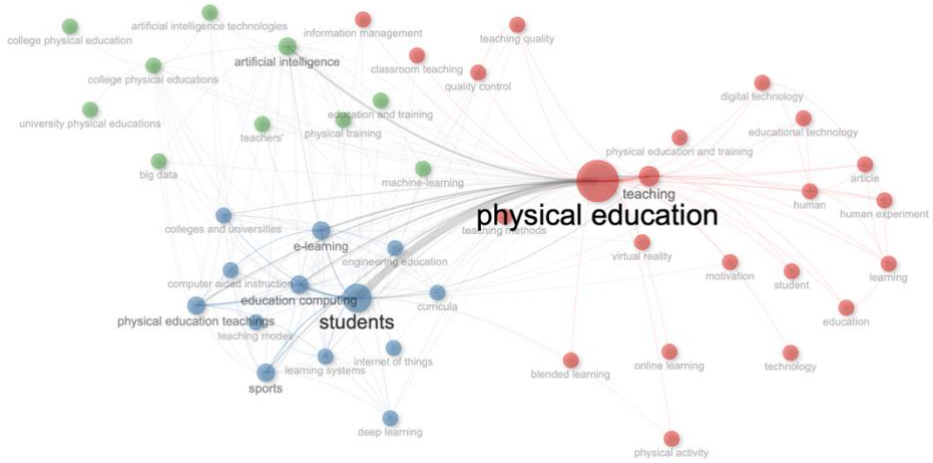

Figure 7. Co-occurrence network of keywords with high frequency in publications about AI-Driven Learning in Physical Education

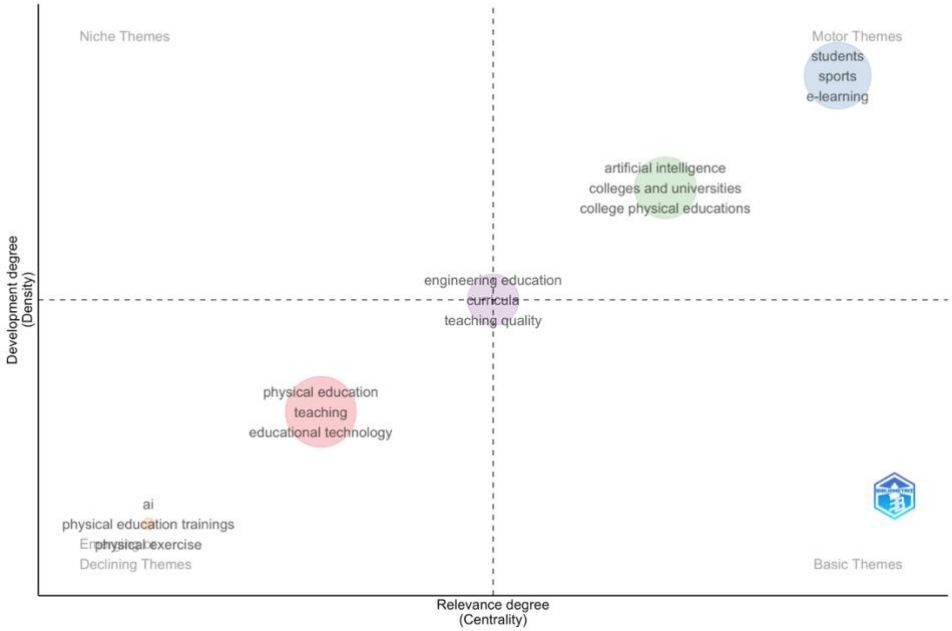

Figure 8. Thematic Map of keywords with high frequency in publications about AI-Driven Learning in Physical Education

The dense interconnections among these clusters indicate that AI-driven learning in physical education is shaped by the integration of pedagogical frameworks, computational intelligence, institutional contexts, and physical training models. Rather than developing as isolated research streams, these thematic clusters collectively form a coherent intellectual structure, underscoring the interdisciplinary and evolving nature of the field.

The thematic map reveals a differentiated conceptual structure of AI-driven learning research in physical education (Figure 8). Motor themes, such as students, sports, and e-learning, occupy the upper-right quadrant, indicating that these topics are both well-developed and central to the field. Basic themes, including artificial intelligence and higher education contexts, demonstrate high relevance but relatively lower internal development, suggesting their role as foundational yet still evolving research areas. Emerging themes related to AI-based physical education training and exercise appear in the lower-left quadrant, highlighting potential avenues for future research. The limited presence of niche themes further indicates that the field remains integrative rather than fragmented.

DISCUSSION

Evolution of AI-Driven Learning Research in Physical Education

This study addresses RQ1 by demonstrating a clear and accelerated growth trajectory of AI-driven learning research in physical education (PE) between 2020 and early 2026. As shown in Figure 2, publication output increased substantially after 2022, indicating a transition from an exploratory phase toward a more consolidated and internationally visible research field. This trend aligns with the broader post-pandemic acceleration of digital transformation in education, where artificial intelligence, learning analytics, and online learning platforms have become integral to pedagogical innovation (Sargent & Casey, 2021; Yang & Qian, 2025).

Beyond the numerical increase in publications, this growth reflects a conceptual evolution in how AI is positioned within PE research. Early studies primarily focused on technological feasibility and system development, whereas more recent publications have increasingly emphasized pedagogical integration, learner engagement, and instructional effectiveness. This shift suggests that AI is no longer framed merely as a technological enhancement but as a pedagogical enabler that supports adaptive learning, individualized feedback, and curriculum innovation in movement-based education (Zhang, 2025).

Influential Authors, Sources, Institutions, and Countries

In response to RQ2, the findings reveal a distributed and heterogeneous structure of scholarly influence across authors, journals, institutions, and countries. As reported in Table 1 and Figure 3, the most productive authors demonstrate relatively modest publication counts, with no single scholar dominating the field. This pattern is characteristic of an emerging interdisciplinary domain, where knowledge production is dispersed across multiple research communities rather than centralized around a small core group (Sargent & Lynch, 2021).

At the source level, Table 2 and Figure 4 highlight an important distinction between publication productivity and citation impact. Journals such as Applied Mathematics and Nonlinear Sciences exhibit a high publication volume but relatively lower citation influence. At the same time, Mobile Information Systems and Education and Information Technologies demonstrate more substantial scholarly

impact despite publishing fewer articles. This discrepancy indicates that visibility and influence in AI-driven PE research are shaped not only by output quantity but also by journal scope, audience, and disciplinary alignment.

Institutional contributions (Table 3; Figure 5) further reinforce the decentralized nature of the field. No single institutional hub dominates research production; instead, contributions are distributed across universities in Asia, Europe, and Oceania. This dispersion reflects varying institutional strategies, research capacities, and national priorities related to AI and educational innovation.

Country-level analysis (Table 4; Figure 6) reveals a more pronounced imbalance. China's overwhelming dominance in publication volume suggests substantial national investment in artificial intelligence, digital education, and large-scale research initiatives. In contrast, contributions from countries such as Spain, Indonesia, and the United States indicate more moderate but steady engagement. These disparities likely reflect differences in national AI policies, research funding structures, and technological infrastructure, which shape the global distribution of research output (Yang, 2024).

Intellectual Structure of AI-Driven Learning in Physical Education

Addressing RQ3, the keyword co-occurrence network (Figure 7) reveals a multi-cluster and highly interconnected intellectual structure. The central positioning of physical education and artificial intelligence confirms that pedagogical objectives and technological innovation are conceptually intertwined rather than operating as parallel research streams. This finding highlights the complexity of integrating AI in PE, where instructional design, learner engagement, and physical performance outcomes must be addressed simultaneously.

The identified clusters demonstrate that AI-driven learning research in PE is shaped by four interrelated dimensions: pedagogical frameworks, computational intelligence, institutional contexts, and physical training models. Such integration supports prior arguments that AI applications in PE are most effective when embedded within instructional and assessment practices rather than implemented as standalone technologies (Guo & Li, 2021; Lee & Lee, 2021; Pill et al., 2021).

Dominant and Emerging Research Themes

With respect to RQ4, the thematic map (Figure 8) provides deeper insight into the conceptual maturity and strategic positioning of research themes. Motor themes, such as students, sports, and e-learning, occupy the upper-right quadrant, indicating that these topics are both central and well-developed within the field. Their prominence reflects sustained scholarly attention to learner-centered pedagogy, technology-supported engagement, and digital learning environments in PE (Sargent & Casey, 2021; Yang & Qian, 2025).

Basic themes related to artificial intelligence and higher education contexts show high relevance but lower internal density, suggesting that while these concepts are foundational, their pedagogical operationalization in PE remains an ongoing research endeavor. Emerging themes located in the lower-left quadrant, such as AI-supported physical training, exercise analytics, and immersive learning, highlight promising but underdeveloped directions that warrant further empirical investigation.

Notably, the limited presence of niche themes suggests that the field has not yet fragmented into isolated research silos. Instead, AI-driven learning in PE appears to be evolving through conceptual integration, where technological innovation is continuously aligned with pedagogical objectives and learning outcomes.

Implications and Future Research Directions

Finally, in addressing RQ5, the findings indicate several critical directions for future research. First, while bibliometric and conceptual studies dominate the current literature, there is a clear need for empirical and longitudinal research examining the effectiveness of AI-driven interventions on motor skill development, physical activity levels, and fitness outcomes (Cheng, 2024; Gil-Espinosa et al., 2022; Li et al., 2025).

Second, teacher-related factors remain underexplored. Successful AI integration in PE depends not only on technological availability but also on teacher professional development, pedagogical competence, and AI literacy (Sargent & Casey, 2021). Future studies should therefore investigate how teachers interpret, adapt, and critically engage with AI-supported instructional tools in diverse educational contexts.

Finally, ethical and equity-related issues including data privacy, algorithmic bias, and unequal access to AI technologies require systematic attention, particularly as AI-driven systems become more embedded in school-based PE environments (Chen & Zeng, 2022; Mason & Kulinna, 2022; Xu & Wang, 2022). Addressing these challenges is essential to ensure that AI-driven learning contributes to inclusive and sustainable educational development rather than reinforcing existing inequalities.

LIMITATIONS OF THE STUDY

However, this study has limitations. First, the database used was only Scopus, not involving other databases such as Web of Science, SportDiscuss, and EBSCO, which also provide several documents related to this study. Second, because only one database was used, the results of this study cannot be generalized.

CONCLUSIONS

This bibliometric study synthesizes the development, intellectual structure, and thematic evolution of AI-driven learning research in physical education. Addressing RQ1, the findings reveal a marked increase in publications, particularly after 2022, indicating a transition from an emerging topic to a rapidly expanding interdisciplinary field driven by AI. In response to RQ2, the analysis reveals a globally distributed yet fragmented research landscape, characterized by dispersed authorship, diverse journal outlets, and uneven national and institutional contributions, with China emerging as the most productive country. Regarding RQ3, the identified multi-cluster intellectual structure demonstrates the close integration of pedagogical frameworks, computational intelligence, institutional contexts, and physical training models, confirming that AI applications in physical education are embedded within teaching and learning processes rather than functioning as standalone technologies. Regarding RQ4, the dominant themes center on pedagogical design, student engagement, adaptive learning systems, and the integration of educational technology. Emerging themes, such as virtual reality, advanced machine learning, and immersive learning environments, indicate a shift toward more personalized and experiential instructional approaches. Finally, addressing RQ5, the findings highlight the need for future research to prioritize empirical and longitudinal studies on learning outcomes, alongside greater attention to teacher professional development, AI literacy, institutional readiness, and ethical considerations, to ensure effective and equitable implementation of AI-driven learning in physical education.

AI DISCLOSURE STATEMENT

The authors declare that artificial intelligence–based tools were used to support language editing, text organization, and refinement of clarity during the manuscript revision process. The use of these tools did not influence the study design, data collection, data analysis, or interpretation of results. All scientific content, analyses, and conclusions remain the sole responsibility of the authors.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to the qualitative nature of the visual analysis and copyright restrictions related to the use of digital children's picture books, the full dataset is not publicly available. However, detailed descriptions of the analyzed materials, analytic procedures, and relevant excerpts are provided within the article to ensure transparency and replicability.

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CONFLICT OF INTEREST

The authors declare that this research is free from conflicts of interest with any party.

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