



Artificial Intelligence in Physical Education Pedagogy: A Bibliometric and Thematic Review of Pedagogical Applications and Emerging Concerns (2015–2025)

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Abstract

Objectives. As artificial intelligence increasingly enters educational practice, PE pedagogy faces a distinct question that extends beyond online, blended, or technology-enhanced delivery. This study mapped research on artificial intelligence in PE pedagogy from 2015 to 2025, focusing on publication growth, conceptual structure, interdisciplinary foundations, pedagogical applications, and emerging concerns.

Materials and Methods. Using a bibliometric and thematic review design, bibliographic data were retrieved from Scopus and analyzed through Bibliometrix/Biblioshiny and VOSviewer. After filtering and data cleaning, the final corpus comprised 1,000 documents published across 389 sources.

Results. The results revealed a marked post-2020 expansion, indicating growing scholarly attention to AI-related pedagogical applications in PE. The field was strongly interdisciplinary, spanning PE, educational technology, computer science, engineering, and health-related domains. Conceptual and thematic analyses showed that the literature is anchored in PE, artificial intelligence, machine learning, deep learning, data mining, physical education teaching, virtual reality, and movement-related analytics. Bibliographic coupling and co-citation analyses further indicated that the field is developing through the convergence of computational innovation and pedagogical application rather than within a single disciplinary tradition.

Conclusions. The study positions AI in PE pedagogy as an emerging computational-pedagogical research domain. The evidence should be interpreted as structural and thematic mapping, not as proof of instructional effectiveness. As a conceptual contribution, the review advances a Pedagogically Accountable AI in PE Framework centered on computational function, pedagogical translation, embodied movement learning, human agency, and ethical accountability.

Keywords: artificial intelligence, bibliometric analysis, emerging concerns, pedagogical applications, physical education.

Introduction

Artificial intelligence (AI) is no longer a peripheral issue in education because it is increasingly shaping how teaching is planned, enacted, assessed, and reflected upon across subject areas. In physical education (PE), this transition is becoming more visible as researchers and practitioners examine how AI may support lesson preparation, instructional decision-making, learner monitoring, performance analysis, feedback generation,

and teacher development (Jastrow et al., 2022; Konukman et al., 2025; Y. Wang & Wang, 2024). Scholarship on digital technology in PE has already established that the subject is not insulated from wider educational transformation, but is instead negotiating how emerging technologies intersect with its curricular aims, pedagogical traditions, and embodied modes of learning (Casey et al., 2017; Jastrow et al., 2022; Lupton, 2022; Østerlie et al., 2025). Yet AI raises a more specific pedagogical problem than broader forms of digitally mediated PE. Online learning, blended delivery, virtual instruction, and technology-enhanced access mainly concern how PE is mediated, delivered, or extended through digital environments. AI, by contrast, can participate in the

pedagogical process itself through classification, prediction, recommendation, adaptation, automation, feedback generation, and decision-support. This makes AI in PE more than a passing technological trend or a general extension of digital learning. It represents a computational-pedagogical frontier where questions of teaching quality, subject integrity, teacher judgment, learner representation, and educational purpose become increasingly entangled with data-driven systems and technological decision-making.

Within this emerging frontier, the literature suggests that AI is beginning to influence core pedagogical work in PE rather than merely serving as an external add-on. Recent studies have shown how AI-supported systems can facilitate reflective practice, generate automated movement-related feedback, strengthen self-assessment, and support more individualized learning processes in PE settings (Hsia et al., 2024, 2025; Huang et al., 2026). At the same time, work on PETE and teacher digital competency indicates that the pedagogical value of new technologies in PE is not determined only by the tools themselves, but also by teachers' professional judgment, digital confidence, curricular interpretation, and assessment literacy (Fletcher et al., 2024; Østerlie et al., 2025; Wallace et al., 2023). Earlier PE pedagogy research likewise showed that mobile applications, video feedback, and digital video can enhance feedback processes, self-assessment, motivation, and learning experiences when technologies are pedagogically integrated rather than simply appended to instruction (J. E. Lee & Gao, 2020; O'Loughlin et al., 2013; Potdevin et al., 2018). These studies suggest that AI-supported PE should not be understood only through the language of technological adoption. Its pedagogical significance lies in how it may reorganize lesson planning, assessment, feedback, learner monitoring, adaptive instruction, and teacher decision-making. However, such possibilities also require caution because AI can intensify long-standing questions about who interprets movement, how student performance is represented, and how teachers balance professional judgment with automated or semi-automated forms of instructional support.

As this literature expands, its development should not be understood solely in terms of technical efficiency or instructional novelty. Broader scholarship on AI in education has shown that AI-supported teaching raises important concerns about data use, teacher agency, transparency, learner representation, and the educational consequences

of automated decision-support (Fu & Weng, 2024; Gouseti et al., 2025; Holmes et al., 2022; Nguyen et al., 2023). These concerns are especially salient in PE because teaching often involves visible, embodied, and interpretive forms of learning in which movement, participation, effort, and competence are observed, assessed, and pedagogically acted upon. Even when such concerns are not consistently foregrounded in the PE literature itself, the growing use of AI in teaching, evaluation, and learning support invites critical attention to how instructional systems are designed, implemented, and justified within educational practice (Baek et al., 2018; Murtagh et al., 2023; Sargent & Calderón, 2021). This critical stance aligns with work urging PE scholars to think carefully about digitality, values, and human flourishing in technologically mediated settings, particularly the argument that PE must remain concerned with learning to be human in a digital world rather than simply adopting technologies for their own sake (Chambers & Sandford, 2019; Fletcher et al., 2024; Murtagh et al., 2023; Standal, 2026; Wallace et al., 2023). In this regard, the present study examines AI in PE pedagogy through a bibliometric and thematic review. Specifically, it maps the growth and intellectual structure of scholarship addressing AI in PE-related teaching and teacher-education contexts. Furthermore, it identifies dominant pedagogical applications and use cases, and synthesizes major thematic directions and emerging concerns associated with AI-supported teaching, assessment, feedback, movement analytics, adaptive instruction, and teacher decision-support (Fu & Weng, 2024; Gouseti et al., 2025; Holmes et al., 2022; Østerlie et al., 2025; Standal, 2026; Y. Wang & Wang, 2024).

Materials and Methods

Research Design

This study employed a bibliometric research design to map the development, collaboration patterns, conceptual structure, and intellectual foundations of research on AI in PE pedagogy. Bibliometric analysis was appropriate because it allows large bodies of scientific literature to be examined through publication, citation, and network-based indicators. Following established bibliometric guidance, the study combined performance analysis and science mapping to examine the field's productivity profile and relational structure (Donthu et

Table 1. Search strategy and inclusion parameters

Parameter	Description
Database & indexes	Scopus
Search field	TITLE-ABS-KEY
Search string	TITLE-ABS-KEY (("physical education" OR "health and physical education" OR "school physical education" OR "physical education teacher education" OR PETE) AND ("artificial intelligence" OR "generative artificial intelligence" OR "machine learning" OR "deep learning" OR ChatGPT OR "large language model*" OR algorithm* OR "learning analytic*") AND (pedagog* OR teach* OR learn* OR instruct* OR assess* OR feedback OR curricul* OR "teacher education" OR "teacher training" OR "reflective practice"))
Language	English
Document types	Article, review, conference paper
Final timespan of corpus	2015–2025
Date of extraction	April 24, 2026

al., 2021; Jiang et al., 2025). This approach was suitable because AI in PE pedagogy spans pedagogical, ethical, assessment-related, teacher education, and technological conversations.

Data Source and Search Strategy

Table 1 presents the search strategy and inclusion parameters. Bibliographic data were retrieved from Scopus, which provides curated multidisciplinary metadata suitable for bibliometric analysis (Baas et al., 2020). The search was conducted in TITLE-ABS-KEY by combining PE terms with AI-related and pedagogy-related terms. This independently constructed search logic delimited AI in PE pedagogy rather than broader digital, online, blended, or technology-enhanced PE. The search was limited to English-language articles, reviews, and conference papers published from 2015 to 2025. Of the 1,383 records retrieved, 1,000 remained after filtering and cleaning.

Corpus Comparison with the Related Digitally Mediated PE Review

To further clarify the independence of the present corpus, a record-level comparison was conducted between the present AI in PE pedagogy dataset and the author's related bibliometric review on digitally mediated PE (Lobo, 2026). The comparison used Scopus EID as the primary matching identifier, with DOI and normalized title used as supporting checks. The present AI in PE pedagogy corpus contained 1,000 records, while the digitally mediated PE corpus contained 1,358 records. A total of 355 records were shared across the two datasets, representing 35.50% of the present AI in PE pedagogy corpus and 26.14% of the digitally mediated PE corpus. Conversely, 645 records, or 64.50% of the present corpus, were unique to this study, while 1,003 records, or 73.86% of the digitally mediated PE corpus, were unique to the related review. This partial overlap was expected because some AI-related work appears within the broader landscape of digitally mediated PE scholarship. However, the majority of records in both corpora were distinct. The digitally mediated PE review was broader in scope and included studies on online learning, blended learning, open distance learning, mobile learning, virtual learning, and technology-enhanced delivery. In contrast, the present corpus was constructed through a separate search strategy centered on AI-related terms and retained only records with substantive links to PE pedagogy, teaching, learning, assessment, feedback, PETE, movement learning, adaptive instruction, or instructional decision-making.

Eligibility Criteria and Corpus Delimitation

Records were included when they matched the finalized search strategy and were indexed in Scopus as English-language articles, reviews, or conference papers. They were retained only when the title, abstract, keywords, or source information showed a substantive link between AI-related approaches and PE pedagogy, teaching, learning, assessment, feedback, PETE, movement learning, or instructional decision-making. Records were excluded when they addressed general educational technology, online or blended learning, distance education, generic AI in education, public health, biomechanics, sport analytics, or computational modeling without an explicit

PE-pedagogy connection. After corpus delimitation, the final dataset comprised 1,000 documents published across 389 sources and authored by 1,748 authors, including 665 articles, 323 conference papers, and 12 reviews.

Data Cleaning and Preprocessing

Before analysis, the records were cleaned to improve metadata consistency and reduce noise, since bibliometric results depend heavily on source metadata quality (Passas, 2024). Cleaning involved checking author names, source titles, and keyword expressions for formatting inconsistencies. Author's Keywords were standardized for spelling, capitalization, hyphenation, pluralization, abbreviations, and closely related variants. When needed, a VOSviewer thesaurus was used to merge semantically equivalent terms. Author's Keywords were prioritized for thematic interpretation because they more directly reflected the authors' stated conceptual emphases, while indexed terms were treated cautiously due to their broader and sometimes less field-specific character.

Bibliometric Analysis

The cleaned dataset was analyzed using Bibliometrix/Biblioshiny and VOSviewer, which supported descriptive profiling, science mapping, and thematic analysis of the field (Aria & Cuccurullo, 2017, 2026; Van Eck & Waltman, 2010). Descriptive analysis summarized annual production, source productivity, citation characteristics, document types, and collaboration indicators. Network analyses examined country-level co-authorship, Author's Keyword co-occurrence, trend topics, source-level bibliographic coupling, and source co-citation. Thematic evolution analysis was also conducted to trace how dominant topics shifted across the study period. Author-level co-authorship was explored but not emphasized because the resulting network was sparse and weakly connected. These procedures were used to assess the productivity, conceptual structure, collaboration patterns, research fronts, intellectual foundations, and thematic development of AI in PE pedagogy.

Network Thresholds and Visualization Parameters

Thresholds were set to balance inclusiveness and interpretive clarity. Author's Keyword co-occurrence used a minimum threshold of 5 occurrences. Author-level co-authorship used a minimum threshold of 3 documents. Source-level bibliographic coupling used a minimum threshold of 4 documents. Lastly, source co-citation used a minimum threshold of 20 citations. Meanwhile, thematic evolution analysis was organized across three periods. In the VOSviewer maps, node size indicated item prominence, link thickness represented relationship strength, and colors identified clusters.

Results

Descriptive Profile and Publication Growth

The final dataset included 1,000 Scopus-indexed documents published from 2015 to 2025, consisting of

665 articles, 323 conference papers, and 12 reviews across 389 sources. The corpus showed an annual growth rate of 46.77%, with an average of 5.72 citations per document and 12.4% international co-authorship. As shown in Figure 1, publication output increased from 5 documents in 2015 to 50 in 2020, then rose sharply to 147 in 2022. Although output declined to 111 documents in 2023, it surged to 294 in 2024 and remained high at 232 in 2025. This pattern indicates the rapid post-2020 expansion of research on AI in PE pedagogy, particularly around teaching, assessment, feedback, movement analytics, and teacher-support applications. Citation averages were higher among earlier publications, especially in 2015 (50.00), 2016 (24.89), and 2018 (12.67), while recent outputs showed lower citation averages, particularly in 2024 (3.36) and 2025 (1.56), because of shorter citation windows.

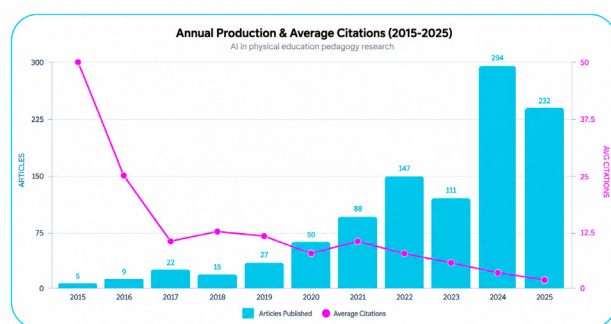


Fig. 1. Annual scientific production in AI in physical education pedagogy research (2015–2025)

Leading Sources, Authors, Affiliations and Influential Documents

The most relevant sources were concentrated in technical, computational, interdisciplinary, and applied publication outlets. Applied Mathematics and Nonlinear Sciences led the corpus with 107 documents, followed by Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering (32), Scientific Reports (24), and MCB Molecular and Cellular Biomechanics (23). Other leading sources included ACM International Conference Proceeding Series and Computational Intelligence and Neuroscience (22), followed by Advances in Intelligent Systems and Computing and Mobile Information Systems (20). Scientific Programming and Journal of Physics: Conference Series also appeared among the most productive outlets. This pattern suggests that research on AI in PE pedagogy is being shaped mainly through computational, engineering, data-driven, and interdisciplinary venues rather than traditional PE pedagogy journals, reflecting the field's development at the intersection of PE, educational technology, AI, analytics, and instructional systems.

The most cited authors were led by Wang, Y. with 104 citations, followed by Lee, H. S. and Lee, J. (47). Other influential authors included Wang, C. (28), Wu, X. (26), Zhang, S. (26), Wang, H. (25), Zhou, T. (24), YanRu, L. (23), and Cao, F. (22). This pattern indicates that author-level

Table 2. Most relevant sources within the corpus (2015–2025)

Sources	Number of articles
Applied Mathematics and Nonlinear Sciences	107
Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering LNICST	32
Scientific Reports	24
MCB Molecular and Cellular Biomechanics	23
ACM International Conference Proceeding Series	22
Computational Intelligence and Neuroscience	22
Advances in Intelligent Systems and Computing	20
Mobile Information Systems	20
Scientific Programming	16
Journal of Physics: Conference Series	14

influence in the corpus is shaped mainly by scholars working on AI-supported PE teaching, instructional evaluation, curriculum innovation, machine vision, and system-based approaches to physical education.

Table 3. Most cited authors within the corpus (2015–2025)

Author	Citations
Wang, Y.	104
Lee, H. S.	47
Lee, J.	47
Wang, C.	28
Wu, X.	26
Zhang, S.	26
Wang, H.	25
Zhou, T.	24
YanRu, L.	23
Cao, F.	22

The most influential documents within the corpus centered on AI-supported PE teaching, intelligent evaluation, machine vision, curriculum design, teaching-resource allocation, and mobile or multimedia-assisted assessment systems. Lee and Lee (2021) led the corpus with 47 local citations and 149 global citations, followed by Zhou et al. (2024) and YanRu (2021) with 23 local citations each. Other influential works included Yang et al. (2020), Z. Li and Wang (2021), Xi Liang and Xi Liang (2022), De-kun and Memon (2022), Zhang (2021), Cao et al. (2022), and S. Li et al. (2024). These documents show that the corpus is intellectually anchored in applied AI work on PE teaching, instructional evaluation, curriculum innovation, movement-related analysis, and system-supported educational practice rather than purely technical or philosophical discussions of artificial intelligence.

At the institutional level, the most productive affiliations were led by Gdansk University of Physical Education and Sport (9), followed by Capital University of Physical Education and Sports, Lviv Polytechnic National University,

Table 4. Most cited documents within the corpus (2015–2025)

Document	Local citations	Global citations
Lee, H. S., & Lee, J. (2021). Applying Artificial Intelligence in Physical Education and Future Perspectives. <i>Sustainability</i> , 13(1), 351. https://doi.org/10.3390/su13010351	47	149
Zhou, T., Wu, X., Wang, Y., Wang, Y., & Zhang, S. (2024). Application of artificial intelligence in physical education: A systematic review. <i>Education and Information Technologies</i> , 29(7), 8203–8220. https://doi.org/10.1007/s10639-023-12128-2	23	47
YanRu, L. (2021). An artificial intelligence and machine vision based evaluation of physical education teaching. <i>Journal of Intelligent & Fuzzy Systems</i> , 40(2), 3559–3569. https://doi.org/10.3233/JIFS-189392	23	39
Yang, D., Oh, E.-S., & Wang, Y. (2020). Hybrid Physical Education Teaching and Curriculum Design Based on a Voice Interactive Artificial Intelligence Educational Robot. <i>Sustainability</i> , 12(19), 8000. https://doi.org/10.3390/su12198000	22	76
Li, Z., & Wang, H. (2021). The effectiveness of physical education teaching in college based on Artificial intelligence methods. <i>Journal of Intelligent & Fuzzy Systems</i> , 40(2), 3301–3311. https://doi.org/10.3233/JIFS-189370	18	38
Xi Liang, X. L., & Xi Liang, J. Y. (2022). Recommendation Algorithm for Equilibrium of Teaching Resources in Physical Education Network Based on Trust Relationship. <i>Journal of Internet Technology</i> , 23(1), 135–143. https://doi.org/10.53106/160792642022012301014	15	55
De-kun, J., & Memon, F. H. (2022). Design of Mobile Intelligent Evaluation Algorithm in Physical Education Teaching. <i>Mobile Networks and Applications</i> , 27(2), 527–534. https://doi.org/10.1007/s11036-021-01818-1	14	43
Zhang, J. (2021). Reform and innovation of artificial intelligence technology for information service in university physical education. <i>Journal of Intelligent & Fuzzy Systems</i> , 40(2), 3325–3335. https://doi.org/10.3233/JIFS-189372	14	50
Cao, F., Xiang, M., Chen, K., & Lei, M. (2022). Intelligent Physical Education Teaching Tracking System Based on Multimedia Data Analysis and Artificial Intelligence. <i>Mobile Information Systems</i> , 2022, 1–11. https://doi.org/10.1155/2022/7666615	14	42
Li, S., Wang, C., & Wang, Y. (2024). Fuzzy evaluation model for physical education teaching methods in colleges and universities using artificial intelligence. <i>Scientific Reports</i> , 14(1), 4788. https://doi.org/10.1038/s41598-024-53177-y	13	15

Table 5. Most relevant affiliations within the corpus (2015–2025)

Affiliation	Articles
Gdansk University of Physical Education and Sport	9
Capital University of Physical Education and Sports	8
Lviv Polytechnic National University	8
South China Normal University	8
Wuhan Sports University	8
Shandong University	7
Xinjiang University	7
Zhengzhou University	7
Beijing Sport University	6
Chengdu Sport University	6

South China Normal University, and Wuhan Sports University (8). Other relevant affiliations included Shandong University, Xinjiang University, and Zhengzhou University (7), followed by Beijing Sport University and Chengdu Sport University (6). This distribution suggests that research on AI in PE pedagogy is supported by sport-focused universities, teacher education settings, and multidisciplinary institutions, indicating that the field is developing across pedagogical, sport, and technological knowledge environments.

Collaborative Structure of the Field

As shown in Figure 2, the country-level co-authorship map indicates that research on AI in PE pedagogy is internationally connected but unevenly integrated. China occupied the most central and visually prominent position, suggesting a strong role in both publication activity and collaborative reach. The United States and the United Kingdom also appeared as well-connected nodes, while South Korea, Japan, Thailand, Malaysia, the Philippines, Portugal, Italy, and Spain contributed to the wider collaboration

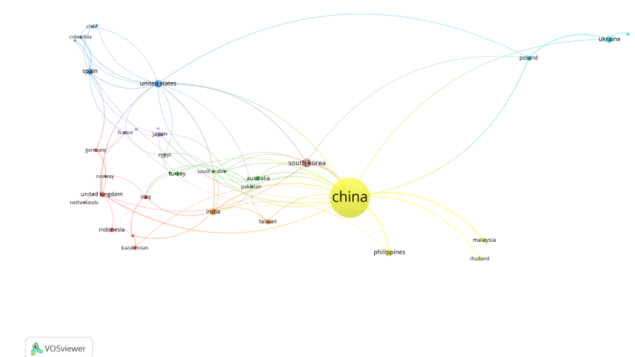


Fig. 2. Country-level co-authorship network in AI in physical education pedagogy research (2015–2025)

structure. The field shows a growing transnational network, although collaboration remains concentrated around a limited number of active country hubs.

The global collaboration map in Figure 3 shows that cross-national collaboration was geographically broad but still concentrated around a few strong country links. The strongest collaborations were between China and Korea (21), China and the Philippines (11), China and Malaysia (7), China and India (5), and China and Poland (5). Other visible collaborations included China with Japan, Thailand, the United Kingdom, Pakistan, Ukraine, and the United States, as well as Spain with Colombia and Mexico, Ukraine with Poland and Slovakia, and the United States with India. Collaboration in AI in PE pedagogy extends across Asia, Europe, North America, and Latin America, although China remains the dominant collaboration hub.

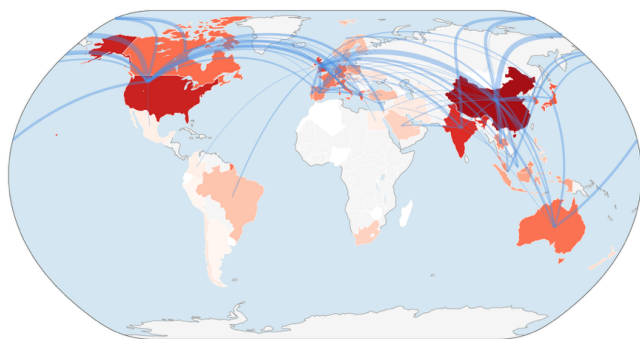


Fig. 3. Global collaboration map in AI in physical education pedagogy research (2015–2025)

Conceptual Structure of the Field

The Author Keywords co-occurrence network in Figure 4 revealed a densely connected conceptual structure anchored by “physical education” and “artificial intelligence.” The yellow cluster centered on “physical education” and included “virtual reality,” “augmented reality,” “student engagement,” and “online physical education,” indicating a strand on immersive and digitally enriched PE learning. The red cluster grouped “data mining,” “big data,” and teaching reform, reflecting data-driven pedagogical improvement. The orange cluster connected “sports,” “college and universities,” “teaching,” and “action recognition,” suggesting applied institutional and instructional use. The blue and cyan clusters contained technical terms such as “deep learning,” “neural network,” “convolutional neural network,” and “internet of things,” representing the computational infrastructure of the field. The purple and pink clusters linked “artificial intelligence,” “machine learning,” and related AI terms, bridging pedagogical and technical strands. The field is structured around immersive PE environments, data-driven teaching improvement, applied instructional deployment, and computational intelligence methods.

Table 6 confirms the centrality of PE and AI-related computational terms in the corpus. “Physical education” was the most frequent Author Keyword with 237 occurrences and the highest total link strength (TLS = 241), followed by “artificial intelligence” (124; TLS = 142), “deep learning” (64), and “machine learning” (56). Other frequent keywords included “physical education teaching,” “data mining,”

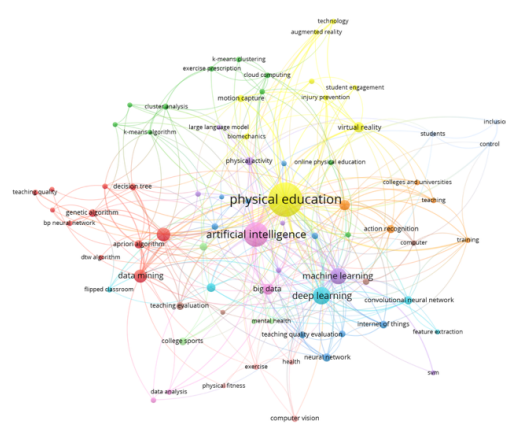


Fig. 4. Co-occurrence network of Author's Keywords in AI in physical education pedagogy research (2015–2025)

“big data,” “sports,” “virtual reality,” and “college physical education.” The keyword profile shows that the corpus is organized around PE as the main educational domain, with major conceptual emphasis on AI, machine learning, deep learning, data mining, teaching, virtual environments, and system-level applications in PE pedagogy.

Table 6. Most frequent Author's Keywords in AI in physical education pedagogy research

Rank	Author's Keyword	Occurrences	Total link strength
1	Physical education	237	241
2	Artificial intelligence	124	142
3	Deep learning	64	74
4	Machine learning	56	63
5	Physical education teaching	38	24
6	Data mining	37	42
7	Big data	26	36
8	Sports	23	38
9	Virtual reality	22	31
10	College physical education	17	18

The trend-topic analysis in Figure 5 shows a temporal shift from earlier performance, biomechanics, and system-processing terms toward more recent AI-enabled and education-facing themes. Earlier topics included “normal human,” “biomechanical phenomena,” and “task performance,” reflecting an initial focus on bodily function, movement performance, and system-level processing. Transitional terms such as “education,” “outcome assessment,” “robotics,” “physiology,” “health,” and “advanced analytics” suggest a widening concern with evaluation and technology-supported educational inquiry. More recent topics, including “physical education,” “students,” “sports,” “teaching,” and “artificial intelligence,” indicate that the field is now more strongly organized around pedagogical practice, learner populations, and AI-supported PE applications. The emergence of “motion capture” and “feature extraction” further suggests growing attention to data-rich movement analysis and computationally supported instruction.

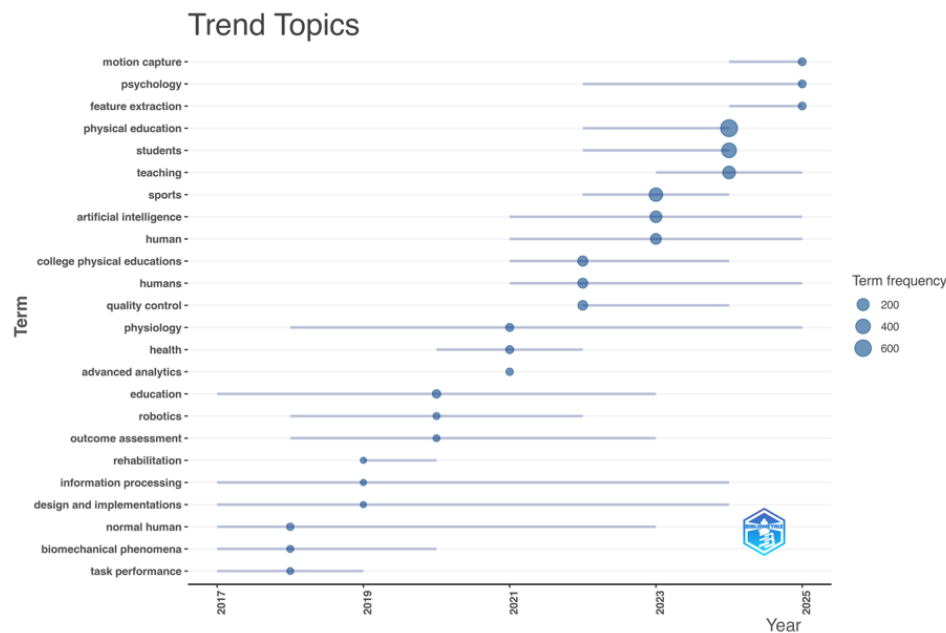


Fig. 5. Trend topics based on Author’s Keywords in AI in physical education pedagogy research (2015–2025)

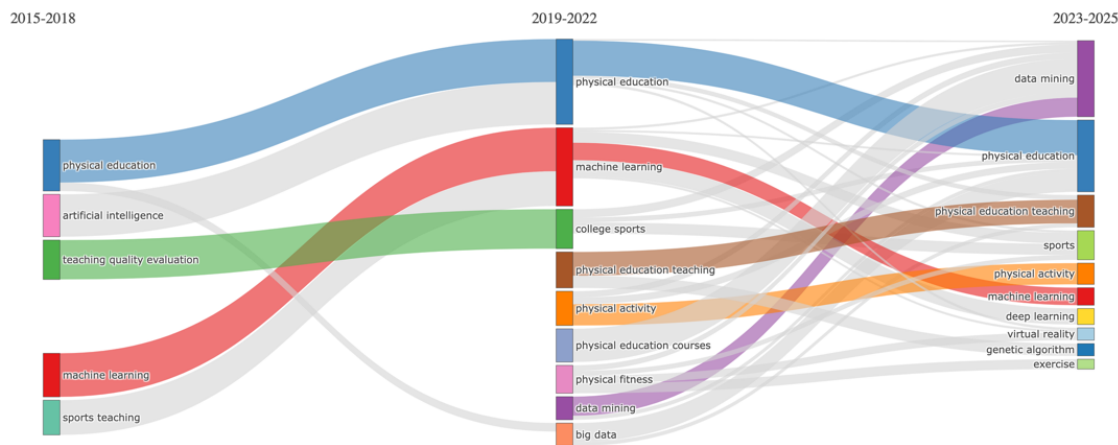


Fig. 6. Thematic evolution of AI in physical education pedagogy research (2015–2025)

The thematic evolution map in Figure 6 shows both continuity and diversification across the field. From 2015–2018, the main themes were “artificial intelligence,” “machine learning,” “physical education,” “sports teaching,” and “teaching quality evaluation,” reflecting early attention to AI concepts, PE instruction, and evaluation-related applications. During 2019–2022, these themes expanded into “physical education,” “machine learning,” “big data,” “data mining,” “college sports,” “physical activity,” “physical education teaching,” and “physical fitness,” indicating a broader connection between computational tools and PE teaching, learning, and movement-related contexts. By 2023–2025, the field consolidated around “physical education,” “physical education teaching,” “data mining,” “machine learning,” “deep learning,” “virtual reality,” “sports,” “genetic algorithm,” and “exercise.” The map suggests a shift from early AI and evaluation-oriented themes toward more specialized work on AI-supported PE teaching, data-driven

analysis, computational movement learning, and immersive instructional applications.

Intellectual Structure of the Field

The source-level bibliographic coupling network in Figure 7 shows a largely integrated but interdisciplinary publication front. Leading connected outlets included “Applied Mathematics and Nonlinear Sciences,” “ACM International Conference Proceeding Series,” “Mobile Information Systems,” “Scientific Reports,” and “Journal of Physical Education, Recreation and Dance.” This pattern indicates that AI in PE pedagogy is being developed across computational, engineering, interdisciplinary science, health-related, educational technology, and PE-oriented publication spaces. Rather than forming a single disciplinary tradition, the field is organized through overlapping computational and pedagogical publication fronts.

Discussion

Artificial Intelligence as Computational Pedagogical Agency in PE

AI should not be treated as a neutral extension of digital PE. Its deeper implication is that it introduces computational agency into pedagogical work. Once a system begins to classify learners, predict needs, recommend tasks, generate feedback, or organize instructional pathways, it is no longer only supporting delivery. It is participating in the production of pedagogical judgment. That shift deserves careful scrutiny because PE has always depended on situated interpretation. Teachers read bodies, emotions, hesitation, effort, confidence, space, risk, and social dynamics in ways that cannot be reduced to data traces. Broader reviews of AI in education show rapid growth around adaptive learning, prediction, assessment, and feedback, but they also show that technological application often develops faster than pedagogical theory (Matos et al., 2025; S. Wang et al., 2024). In PE, that imbalance may be even more consequential because movement learning is not only a technical process. It is relational, affective, embodied, and culturally situated. The danger is not simply that AI will enter PE. The danger is that PE problems may be reframed too quickly as optimization problems. Lesson planning may become sequencing by recommendation. Differentiation may become grouping by predicted ability. Support may become automated intervention. In practical lesson planning, this means that AI may influence how teachers select learning tasks, sequence movement activities, group students, anticipate difficulty, and adapt instruction based on predicted learner needs. Such support may make planning more responsive, but it may also narrow pedagogical imagination when teachers begin to design lessons around algorithmic recommendations rather than curricular purpose, embodied readiness, and student experience. These are not inherently wrong, but they change the center of pedagogical authority. Therefore, AI in PE requires more than adoption studies or tool evaluations. It requires a theory of how computational systems should remain answerable to the educational meaning of movement, rather than allowing movement to be reorganized around what machines can detect and process.

Algorithmic Assessment and Feedback in Embodied Movement Learning

Assessment and feedback are among the most tempting uses of AI in PE because they promise immediacy, precision, and scalability. A system that can detect movement patterns, identify errors, and generate feedback appears to solve a practical problem that PE teachers regularly face. Recent work on AI-based real-time feedback has shown how such systems may support movement quality, fluency, learning interest, and self-directed learning (Ma et al., 2025). Yet, the critical issue is not whether AI can assess movement. The issue is what kind of movement becomes assessable when AI becomes part of the assessment ecology. PE does not deal with movement as pure mechanics. A jump, throw, step, kick, or dance phrase carries intention, fear, rhythm, fatigue, confidence, memory, and social exposure. Algorithmic feedback may capture angles, speed, timing, posture, or error patterns, but these indicators do not exhaust the educational

meaning of movement. At the level of assessment, AI may shift PE from episodic teacher observation toward continuous movement capture, automated error detection, and performance profiling. This changes feedback from a relational exchange between teacher and learner into a mediated process shaped by what the system can detect, classify, and report. The pedagogical concern is not only accuracy, but whether AI-generated feedback helps students understand movement in ways that are meaningful, safe, and confidence-building. Datafication scholars have long argued that digital systems do not merely represent reality; they shape what institutions learn to value and act upon (Jarke & Breiter, 2019; Williamson et al., 2020). In PE, this means that AI feedback may quietly privilege measurable correctness over felt learning, experimentation, expression, and bodily confidence. Wearable and monitoring technologies already show how PE can slide into uncritical bodily surveillance when data are treated as naturally useful (Cereda, 2025). Thus, a critical AI pedagogy in PE should ask whether assessment expands students' movement possibilities or disciplines them into algorithmically preferred forms of performance. Feedback should help students understand movement, not make them feel permanently watched by a system that knows their body only through metrics.

Teacher Agency and Professional Judgment in AI Supported PE

The teacher's role becomes more complicated, not less, when AI enters PE. The common language of AI support can make the technology sound harmless, as though the teacher remains fully in control while the system quietly assists in the background. In practice, AI-generated classifications, recommendations, alerts, and feedback can carry strong pedagogical authority. Teachers may begin to trust them, adjust instruction around them, or feel pressured to justify decisions against them. This affects teacher decision-making at several levels. AI may suggest which students need remediation, which skills require further practice, which activities should be modified, or which learners are ready to progress. These suggestions can support teacher reflection, but they can also subtly redistribute authority from professional judgment to system-generated interpretation. Therefore, the teacher's pedagogical task, is not simply to use AI output, but to decide when it is educationally relevant, when it is incomplete, and when it must be resisted. This creates a new professional demand. PE teachers must not only know how to use AI tools; they must know how to disagree, reinterpret, and sometimes ignore them. Research on digital competency in PE and PETE already shows that technology integration depends on teachers' assessment literacy, curricular judgment, and professional confidence (Fletcher et al., 2024; Østerlie et al., 2025; Wallace et al., 2023). AI intensifies that requirement because the tool does not only display content or record performance. It interprets. Wider studies on teachers and AI have warned that application-focused research often outpaces professional development and pedagogical preparation (K. Li et al., 2025; Tan et al., 2025). For PE, this gap cannot be treated as a minor implementation issue. A teacher who cannot critically interpret AI output may become dependent on systems that flatten students into profiles, scores, risk categories,

or movement errors. Recent discussions of generative AI also stress that agency and decision-making must remain with educators rather than being transferred to automated systems (Alfarwan, 2025; Landa-Blanco, 2026). Hence, PE teachers should be positioned not as end-users of AI, but as critical pedagogical mediators. Their work is to translate, question, contextualize, and humanize AI outputs within the lived realities of movement learning.

Student Autonomy Datafication and the Ethics of AI Mediated PE

Student autonomy is often used to justify AI in education. Personalized goals, adaptive feedback, progress dashboards, and self-monitoring tools can appear to give students more control over learning. In PE, this promise is attractive because students differ widely in confidence, ability, body history, prior exposure, injury, motivation, and comfort with public performance. Yet, autonomy becomes thin when it is defined only as the ability to follow personalized data. A student may receive more feedback, tracking, and individualized recommendations while having less power to question how their body is being interpreted. For students, AI-supported autonomy may become a form of guided compliance if individualized recommendations are treated as instructions to follow rather than information to interpret. In movement learning, this is especially important because progress is not only demonstrated through technical correction or measurable improvement. It may also appear through confidence, rhythm, willingness to participate, creative exploration, bodily comfort, and the ability to make sense of one's own movement. Broader AI-in-education scholarship has raised continuing concerns about privacy, transparency, bias, learner representation, and the balance between automation and human control (Holmes et al., 2022; Nguyen et al., 2023). Human-centered work on learning analytics similarly emphasizes trust, safety, end-user involvement, and meaningful oversight rather than technical performance alone (Alfredo et al., 2024). These concerns become sharper in PE because the student body is already an object of observation. AI can make that observation more continuous, more granular, and more difficult to refuse. The ethical problem is not only data privacy. It is also bodily dignity. Students should not experience AI-mediated PE as a condition where every movement becomes evidence, every performance becomes a record, and every body becomes a dataset. Chambers and Sanford's (2019) reminder that PE should remain concerned with learning to be human in a digital world is especially relevant. A humane AI agenda in PE must protect the student's right to move imperfectly, privately, playfully, and experimentally. Autonomy should mean more than being guided by AI. It should include understanding, consent, contestation, and the freedom to remain more than what the system measures.

Toward a Pedagogically Accountable AI in PE Framework

This review proposes a Pedagogically Accountable AI in PE Framework as a conceptual contribution for future research and practice. AI integration in PE should not be evaluated only through technical accuracy, automation, prediction, or efficiency. It should also be judged according

to how it protects pedagogical judgment, embodied learning, student agency, and ethical responsibility. Human-centered AI scholarship has emphasized the need for human control, stakeholder involvement, trustworthiness, and safety in learning analytics and AI-supported education (Alfredo et al., 2024; Holmes et al., 2022). In PE, these concerns become more urgent because learning is bodily, visible, social, and emotionally charged. The proposed framework positions AI not as an independent pedagogical authority, but as a system that must be translated, questioned, and ethically governed before it becomes part of movement learning.

Figure 9 presents the proposed Pedagogically Accountable AI in PE Framework as a conceptual model for interpreting AI-supported PE practice. The model begins with computational function, which refers to what AI systems can technically perform, such as classification, prediction, recommendation, automation, movement recognition, assessment support, and feedback generation. These functions do not move directly into PE practice. They must pass through pedagogical translation, embodied movement learning, human agency, and ethical accountability before becoming educationally meaningful. Therefore, the proposed model frames AI-supported PE practice as a mediated outcome rather than a direct result of technological capability. In this proposed framework, lesson planning, assessment, feedback, movement analytics, teacher-supported decision-making, and inclusive participation remain accountable to teacher judgment, student agency, embodied experience, and ethical safeguards.

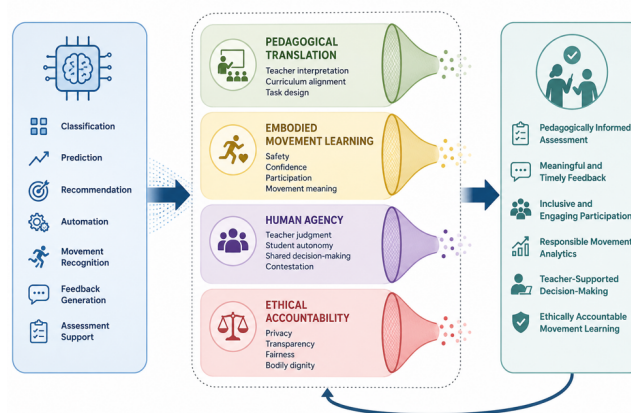


Fig. 9. Pedagogically Accountable AI in PE Framework.

Note: The framework illustrates how AI-supported PE should move from computational functions toward educational practice through pedagogical translation, embodied movement learning, human agency, and ethical accountability. The curved arrow indicates that AI-supported PE practice requires continuous review, interpretation, and adjustment rather than direct application of system-generated outputs

Computational Function

This refers to what AI systems are designed to do in PE. These functions may include classifying movement, detecting errors, predicting learner needs, recommending tasks, automating assessment, generating feedback, or supporting instructional decisions. Recent reviews of AI-based learning tools show that assessment, personalized

feedback, recommendations, and intelligent tutoring are now among the most common roles of AI in education (Luo et al., 2025). These functions may be useful in PE because teachers often handle large classes, varied skill levels, limited time, and complex movement tasks. Yet computational function should not be confused with pedagogical value. A system may accurately detect movement patterns without understanding why a student moves cautiously, avoids participation, or struggles with a task. This dimension describes what AI can process, but not what PE should value.

Pedagogical Translation

This concerns the work of turning AI outputs into meaningful instruction. Data, alerts, scores, and recommendations do not automatically become pedagogical knowledge. Teachers still need to interpret them, connect them to lesson objectives, adjust tasks, and decide whether automated feedback fits the learner, activity, and class context. This is especially important because AI in education has often developed faster in classroom application than in teacher professional development. Tan et al. (2025) found that research on AI in teaching remains more focused on application than on the professional learning teachers need to integrate AI responsibly. In PE, that gap is risky. A movement score, posture alert, or performance prediction may look objective, but it still requires professional interpretation. PE teachers need to decide whether AI feedback supports learning, reinforces narrow performance standards, or misreads the learner's embodied situation. This dimension keeps AI under the authority of curriculum, context, and teacher judgment.

Embodied Movement Learning

This keeps attention on what makes PE educationally distinctive. Movement is not only a biomechanical event or a performance output. It carries confidence, fear, rhythm, hesitation, fatigue, safety, enjoyment, social exposure, and cultural meaning. Chambers and Sandford (2019) argued that PE should remain concerned with learning to be human in a digital world, a point that becomes sharper when AI begins to evaluate bodies and movement. AI may support skill correction or performance feedback, but it may also push PE toward a narrow culture of monitoring and optimization. Datafication scholars have warned that digital systems shape what schools learn to see, value, and act upon (Jarke & Breiter, 2019; Williamson et al., 2020). In PE, movement can become too quickly translated into indicators, scores, alerts, and risk profiles. Therefore, AI-supported PE must remain accountable to embodied learning. The goal is not simply better measurement. The goal is richer, safer, more meaningful, and more inclusive movement participation.

Human Agency

This positions teachers and students as active interpreters of AI-supported PE. They should not become passive recipients of system-generated recommendations. Alfarwan (2025) emphasized that GenAI may support teaching and learning, but agency and decision-making must remain with teachers. This principle is crucial because teachers work

with situated, relational, and affective forms of learning. They notice embarrassment, overconfidence, discomfort, resistance, peer dynamics, and fear of failure. AI cannot fully read these conditions. Students also need agency in how AI feedback is received, questioned, and used. A learner should not be positioned as a body waiting to be corrected by a system. This dimension means that teachers can challenge AI outputs, students can understand and contest feedback, and both remain central to the learning process. Without this dimension, AI-supported PE may become efficient but disempowering. It may produce more information while reducing the human capacity to interpret, negotiate, and make meaning from movement.

Ethical Accountability

Ethical accountability is the dimension that prevents the framework from becoming a purely technical model of AI integration. It requires transparency, privacy, fairness, consent, anti-surveillance, and bodily dignity because AI use in PE often involves data about bodies, movement, performance, effort, fitness, participation, and learning behavior. These are not neutral data points. They can shape how students see themselves, how teachers interpret ability, and how institutions define improvement, risk, or readiness. Human-centered learning analytics research has shown that students and teachers are not always sufficiently involved in the design of AI-supported educational systems, even when these systems directly affect their learning and agency (Alfredo et al., 2024). Broader AI ethics scholarship in education also warns about bias, opacity, privacy, and the difficulty of balancing automation with human judgment (Holmes et al., 2022; Nguyen et al., 2023). For this reason, this dimension functions as the framework's critical safeguard. It asks whether AI-supported PE expands dignity, participation, and meaningful movement learning, or whether it intensifies surveillance, ranking, correction, and data-driven control. A system that tracks students efficiently but makes them feel watched, exposed, ranked, or reduced to bodily metrics is not pedagogically accountable, regardless of its technical sophistication.

Framework Contribution

The proposed Pedagogically Accountable AI in PE Framework rejects a linear model in which AI produces data and teachers simply apply it. AI outputs must pass through pedagogical translation, embodied context, human agency, and ethical scrutiny before becoming educational action. The framework is not presented as an empirically validated model. Rather, it is a conceptual contribution derived from the bibliometric and thematic synthesis. It offers a way to organize future research around a stronger question. AI-supported PE should not only ask whether systems work, but what kind of PE they help create. If AI strengthens teacher judgment, expands student participation, supports meaningful feedback, and protects bodily dignity, it may enrich PE pedagogy. If it narrows movement into monitoring, correction, prediction, and optimization, it risks weakening the educational purpose of the subject. This framework positions AI in PE as a pedagogical and ethical problem before it is a technical solution.

Conclusions

This review positions AI in PE pedagogy as more than a technical innovation. It is an emerging computational-pedagogical field that may reshape how movement is taught, assessed, interpreted, and experienced. Its central contribution is the Pedagogically Accountable AI in PE Framework, which argues that AI-supported PE must be judged not only by what systems can detect, automate, or optimize, but by how they protect pedagogical judgment, embodied learning, human agency, and ethical responsibility. The review does not establish the effectiveness of AI in PE. It shows instead that the field is entering a critical stage where future scholarship must decide whether AI will deepen the educational meaning of movement or reduce PE to monitoring, correction, and data-driven performance management.

Conceptual and practical implications

The review positions AI in PE pedagogy as a cross-cutting concern that requires stronger integration across PE pedagogy, PETE, educational technology, learning analytics, computer science, movement science, assessment studies, ethics, and teacher professional development. Conceptually, this means moving beyond tool-centered or innovation-centered accounts of AI toward a deeper understanding of how computational systems may reorganize lesson planning, assessment, feedback, teacher agency, student autonomy, and embodied movement learning. In practical terms, PE teachers, teacher educators, curriculum designers, school leaders, researchers, and AI developers should treat AI as a pedagogical system that requires interpretation, adaptation, and ethical scrutiny. AI-supported PE should be designed around teacher judgment, learner dignity, transparent feedback, meaningful assessment, inclusive participation, and responsible data use. The proposed framework encourages stakeholders to treat AI not as a substitute for PE teachers or as a neutral technical upgrade, but as a mediated pedagogical resource that must remain accountable to the educational purpose of movement.

Future research directions

Future research should move beyond mapping the growth of AI in PE pedagogy and examine how AI-supported systems actually function in teaching and learning contexts. Empirical studies are needed to test how AI affects lesson planning, assessment quality, feedback processes, student autonomy, teacher agency, and embodied movement learning. More work is also needed on PE teacher preparation, AI literacy, ethical decision-making, and professional development, particularly because AI outputs require pedagogical interpretation rather than direct application. Future studies should also examine students' lived experiences of AI-mediated PE, including issues of privacy, surveillance, confidence, inclusion, and bodily dignity. Finally, the proposed Pedagogically Accountable AI in PE Framework should be tested, refined, or challenged across different PE settings, learner groups, technologies, and cultural contexts.

Ethics Approval

This study relied exclusively on bibliographic records indexed in Scopus and did not involve human participants,

personal data, or direct intervention. This study has been exempted for ethical review by the Bulacan State University-Research Ethics Committee (BulSU-ERC) BulSUERC-2026-0124-EX.

Data Availability Statement

The bibliometric data that support the findings of this study were retrieved from the Scopus database. The dataset generated and analyzed during the current study, including the cleaned bibliographic records and thesaurus files used for mapping and visualization, is available from the author upon reasonable request, subject to database access and licensing restrictions.

AI Transparency Statement

During the preparation of this manuscript, the author used ChatGPT 5.4+ by OpenAI in a limited and supportive capacity for language refinement, organizational assistance, and drafting support. The author retained full control over the intellectual content of the manuscript and was solely responsible for the study design, search strategy, data analysis, interpretation, and final revision of the text. All AI-assisted outputs were carefully reviewed, edited, and validated by the author, who accepts full responsibility for the final submitted version.

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Conflicts of Interest

The author declares no conflict of interest.

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Штучний інтелект у педагогіці фізичного виховання: бібліометричний і тематичний огляд педагогічних застосувань та нових проблем (2015–2025)

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

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Мета. Оскільки штучний інтелект дедалі активніше впроваджується в освітню практику, педагогіка фізичного виховання стикається з окремим колом питань, що виходять за межі онлайн-, змішаного або технологічно підтримуваного навчання. Метою цього дослідження було здійснити картування наукових публікацій щодо штучного інтелекту в педагогіці фізичного виховання за 2015–2025 роки з акцентом на динаміці публікаційної активності, концептуальній структурі, міждисциплінарних засадах, педагогічних застосуваннях і нових проблемних аспектах.

Матеріали та методи. Дослідження виконано у форматі бібліометричного та тематичного огляду. Бібліографічні дані було отримано з бази Scopus та проаналізовано за допомогою Bibliometrix/Biblioshiny і VOSviewer. Після фільтрації та очищення даних остаточний корпус становив 1000 документів, опублікованих у 389 джерелах.

Результати. Результати засвідчили суттєве зростання кількості публікацій після 2020 року, що вказує на посилення наукового інтересу до педагогічних застосувань штучного інтелекту у фізичному вихованні. Дослідницьке поле має виразно міждисциплінарний характер і охоплює фізичне виховання, освітні технології, комп'ютерні науки, інженерію та науки про здоров'я. Концептуальний і тематичний аналіз показав, що література зосереджена навколо таких напрямів, як фізичне виховання, штучний інтелект, машинне навчання, глибоке навчання, інтелектуальний аналіз даних, викладання фізичного виховання, віртуальна реальність та аналітика рухової діяльності. Аналіз бібліографічного зв'язку та співцитування також засвідчив, що це дослідницьке поле формується внаслідок конвергенції обчислювальних інновацій і педагогічного застосування, а не в межах однієї дисциплінарної традиції.

Висновки. Штучний інтелект у педагогіці фізичного виховання позиціонується як новий обчислювально-педагогічний напрям досліджень. Отримані результати слід розглядати як структурне й тематичне картування наукового поля, а не як доказ ефективності застосування штучного інтелекту в навчальному процесі. Як концептуальний внесок у розвиток напрямку в огляді запропоновано Рамкову модель педагогічно відповідального штучного інтелекту у фізичному вихованні, зосереджену на обчислювальній функції, педагогічній трансляції, навчанні через рухову діяльність, людській суб'єктності та етичній відповідальності.

Ключові слова: штучний інтелект, бібліометричний аналіз, нові проблемні аспекти, педагогічні застосування, фізичне виховання.

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