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Scientific Technical Journal of School Sport, Physical Education and Psychomotricity

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ISSN-e 2386-8333

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Enhancing physical literacy in physical education: a systematic review of deep learning approaches

Mejorar la alfabetización física en la educación física: una revisión sistemática de los enfoques de aprendizaje profundo

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Editorial schedule: *Article received 11/06/2025 Accepted: 18/12/2025 Published: 01/04/2026*

https://doi.org/10.17979/sportis.2026.12.2.12325

To cite this article use the following reference:

Al Ardha, M.A.; Nurhasan, N.; Nur, L.; Chaeroni, A.; Yang, C.B.; Bikalawan, S.S.; Indriarsa, N.; Hamdani, H. (2026). Enhancing physical literacy in physical education: a systematic review of deep learning approaches. *Sportis Sci J*, 12 (2), 1-38 https://doi.org/10.17979/sportis.2026.12.2.12325

Author contribution: Study Design (Al Ardha, M.A.; Nurhasan, N; Yang, C.B.), Method (Al Ardha, M.A.; Nur, L.; Chaeroni, A.; Bikalawan, S.S.), Result (Nur, L.; Chaeroni, A.; Bikalawan, S.S.; Indriarsa, N.; Hamdani, H.), Discussion (Al Ardha, M.A.; Indriarsa, N.; Hamdani, H.), Funds Collection (Nurhasan, N; Yang, C.B.)

Funding: This research received support from Universitas Negeri Surabaya via an RKI 2025 funding program.

Conflict of interest: The author declared there is no conflict of interest.

Ethical aspects: Not required.

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Abstract
The integration of deep pedagogical learning has shifted physical education from traditional instruction toward intellectually stimulating and student-centered methodologies. The objective is to explore the impact of implementing deep pedagogical learning on the latest technological advances. This study is a systematic review. It uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to ensure transparency in the data collection process. This study uses the SCOPUS, ERIC, PubMed, and IEEE Xplore databases. In addition, this study uses Publish or Perish software as a screening tool and VosViewer software as a keyword analysis tool. The exclusion criteria set in this study are studies that are not published in the form of articles, have the same title, are retracted, and are irrelevant. The inclusion criteria established were studies published in the form of articles and relevant to the topic of this study. Based on the screening results, 58 relevant research data points were obtained, and 10 of them were used as a literature review determined based on the most cited articles. The systematic review results presented how technology has a considerable influence on physical education learning. The finding indicates deep pedagogical learning is proven to improve the quality of physical education, both for students, teachers, and the learning process itself.

Keywords: artificial intelligence; critical thinking; learning technology; students skills; teacher pedagogy

Resumen
La integración del aprendizaje pedagógico profundo ha cambiado la educación física, pasando de la enseñanza tradicional a metodologías intelectualmente estimulantes y centradas en el alumno. El objetivo es explorar el impacto de la implementación del aprendizaje pedagógico profundo en los últimos avances tecnológicos. Este estudio es una revisión sistemática. Utiliza el método Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) para garantizar la transparencia en el proceso de recopilación de datos. Este estudio utiliza las bases de datos SCOPUS, ERIC, PubMed e IEEE Xplore. Además, este estudio utiliza el software Publish or Perish como herramienta de selección y el software VosViewer como herramienta de análisis de palabras clave. Los criterios de exclusión establecidos en este estudio son los estudios que no se publican en forma de artículos, tienen el mismo título, se retiran y son irrelevantes. Los criterios de inclusión establecidos fueron estudios publicados en forma de artículos y relevantes para el tema de este estudio. A partir de los resultados de la selección, se obtuvieron 58 puntos de datos de investigación relevantes, y 10 de ellos se utilizaron como revisión bibliográfica determinada en función de los artículos más citados. Los resultados de la revisión sistemática mostraron cómo la tecnología tiene una influencia considerable en el aprendizaje de la educación física. El hallazgo indica que se ha demostrado que el aprendizaje pedagógico profundo mejora la calidad de la educación física, tanto para los estudiantes como para los profesores y el propio proceso de aprendizaje.

Palabras clave: inteligencia artificial; pensamiento crítico; tecnología del aprendizaje; competencias de los alumnos; pedagogía docente

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Introduction

Physical Education (PE) fosters physical health and cognitive and socio-emotional development among students (Wibowo et al., 2023). Traditional PE instruction often emphasizes skill acquisition and physical performance, sometimes neglecting higher-order cognitive engagement (Hector & Salinitri, 2022). However, contemporary educational paradigms advocate for approaches that integrate critical thinking, problem-solving, and active student participation (Baena-Morales, Merma-Molina, & Ferriz-Valero, 2023;. In this context, Deep Learning (DL) is a pedagogical approach (Walker et al., 2021). It is essential to differentiate pedagogical deep learning from the similarly named computational technique in artificial intelligence. In this study, deep learning refers specifically to a student-centered approach that fosters deep cognitive engagement with the content. DL, rooted in mindful learning, meaningful learning, and joyful learning has emerged as a transformative strategy to enhance PE's cognitive and affective dimensions.

This transformative learning approaches transcends rote memorization by promoting higher-order thinking skills (HOTS), which include analysis, evaluation, and creativity (Phillips & O'flaherty, 2019). Unlike surface-level learning, DL encourages students to engage deeply with content, apply knowledge in real-world contexts, and reflect on their learning experiences (Roslan et al., 2021). Integrating Artificial Intelligence (AI) and machine learning further extends DL's potential by enabling adaptive, personalized, and data-driven educational instructional strategies (Aggarwal et al., 2022).

In PE, DL approach can revolutionize how students interact with movement concepts, tactical games, and health-related fitness knowledge (Q. Li et al., 2022). By incorporating inquiry-based learning, problem-based learning (PBL), and project-based learning (PjBL), educators can foster critical thinking, collaboration, and metacognitive awareness among students (Østergaard, 2016). Moreover, high engagement learning aligns with constructivist and experiential learning theories, where students actively construct knowledge through hands-on experiences and reflective practices (Huang & Yu, 2022).

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Despite the well-documented benefits of deep learning in general education, its application in physical education remains significantly underexplored. Many PE programs follow traditional, teacher-centered approaches, emphasizing repetitive drills and skill execution over cognitive engagement (Mesnan et al., 2023; Oktofanny et al., 2023). While these methods may improve short-term motor performance, they often fail to foster long-term knowledge retention, critical thinking, or meaningful learning experiences. Furthermore, although Artificial Intelligence (AI) and machine learning have been widely adopted in subjects like mathematics and science (Erduran & Levrini, 2024; Rajdeep, 2024), their potential to enhance motor skill acquisition, tactical decision-making, and student motivation in PE has not been thoroughly examined through a systematic review.

Several key gaps persist in the current literature. First, there is a lack of empirical studies focusing on DL approach explicitly designed for PE contexts. Second, while DL principles such as mindful, meaningful, and joyful learning have been discussed in broader educational research, their practical implementation in PE remains unclear. Third, despite the growing use of AI-driven tools (e.g., motion tracking, virtual reality, gamification) in education, there is limited synthesized evidence on how these technologies can support DL approach in PE settings. Addressing these gaps is crucial for advancing evidence-based, student-centered PE pedagogies that align with the evolving demands of 21st-century education.

This systematic review seeks to achieve four primary objectives. First, it aims to examine existing deep learning frameworks applied in physical education, identifying their key components and theoretical foundations. Second, it will evaluate the impact of DL on critical thinking and student engagement in PE, assessing how these approaches influence cognitive and affective learning outcomes. Third, the review will identify AI and technology-enhanced strategies that facilitate transformative learning approach in PE, exploring innovations such as wearable sensors, augmented reality, and adaptive learning systems. Finally, it will highlight best practices and challenges in implementing DL within PE curricula, providing actionable insights for educators, curriculum designers, and policymakers. By addressing these objectives, this study aims to bridge

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the gap between theoretical research and practical application, ultimately contributing to more dynamic, engaging, and cognitively enriching PE experiences for students.

Method

Study design

This study is a systematic review that adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological rigor and transparency. The study employs a comprehensive search strategy across multiple academic databases, including SCOPUS, ERIC, PubMed, and IEEE Xplore, to identify relevant literature on deep learning implementations in physical education.

Study procedure

Data identification was carried out using the keywords “deep learning” and “physical education” on 27 March 2025 through the web pages of the four databases used (SCOPUS, ERIC, PubMed, and IEEE Xplore). The results of the research data identification were then exported in RIS form for the research data screening process through the Publish or Perish (PoP) software. PoP has the capability to screen research data through its feature of grouping research documents based on year and type of publication. In addition, PoP is also able to group research based on research titles to identify research documents with the same title. Thus, the process of screening research data can be carried out more effectively and efficiently.

Researchers also establish exclusion and inclusion criteria based on the research objectives, so that the results identified and used in the systematic review will be appropriate and provide coherent and comprehensive information. The exclusion criteria set by researchers are research documents published not in the form of articles, articles retracted by publishers, articles with the same title, and articles that do not discuss DL in PE. Meanwhile, the inclusion criteria are documents published in the form of articles that discuss DL in PE. The results of the screening process will be exported back in RIS form for keyword analysis uses VosViewer software.

After identifying relevant research that met the inclusion and exclusion criteria, the research procedure continued by selecting 10 articles with the highest number of

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citations for literature review. In this case, the researchers involved three experts who were qualified in understanding the deep learning approach, specifically in physical education.

Following the initial literature search, a thematic analysis will be conducted to systematically categorize findings into three key domains: (1) cognitive engagement, focusing on how DL strategies enhance critical thinking and problem-solving in PE; (2) affective outcomes, examining the impact of DL on student motivation, enjoyment, and emotional well-being; and (3) technological innovations, analyzing the role of AI-driven tools, such as motion tracking and virtual reality, in supporting DL approaches. This structured methodology ensures a rigorous synthesis of existing knowledge while identifying gaps and opportunities for future research in the field.

Result

Based on the results of the identification and screening process of research data from SCOPUS, ERIC, PubMed, and IEEE Xplore databases, 531 research documents were obtained (Figure 1). Each database contributes to DL research in PE through its publication quality (Table 1). The identified documents need to go through a filtering process to obtain results relevant to this research topic. A total of 352 research documents has been selected, and only 58 research documents in the form of articles apply to this research topic (Figure 1). The relevant documents will be sorted again based on the most citations, and then a literature review of the sorted results will be conducted. This sorting process involves PoP software to ensure appropriate results and minimize possible bias. This software is also a tool for researchers to classify or look at the characteristics of publications in each database (Table 1).

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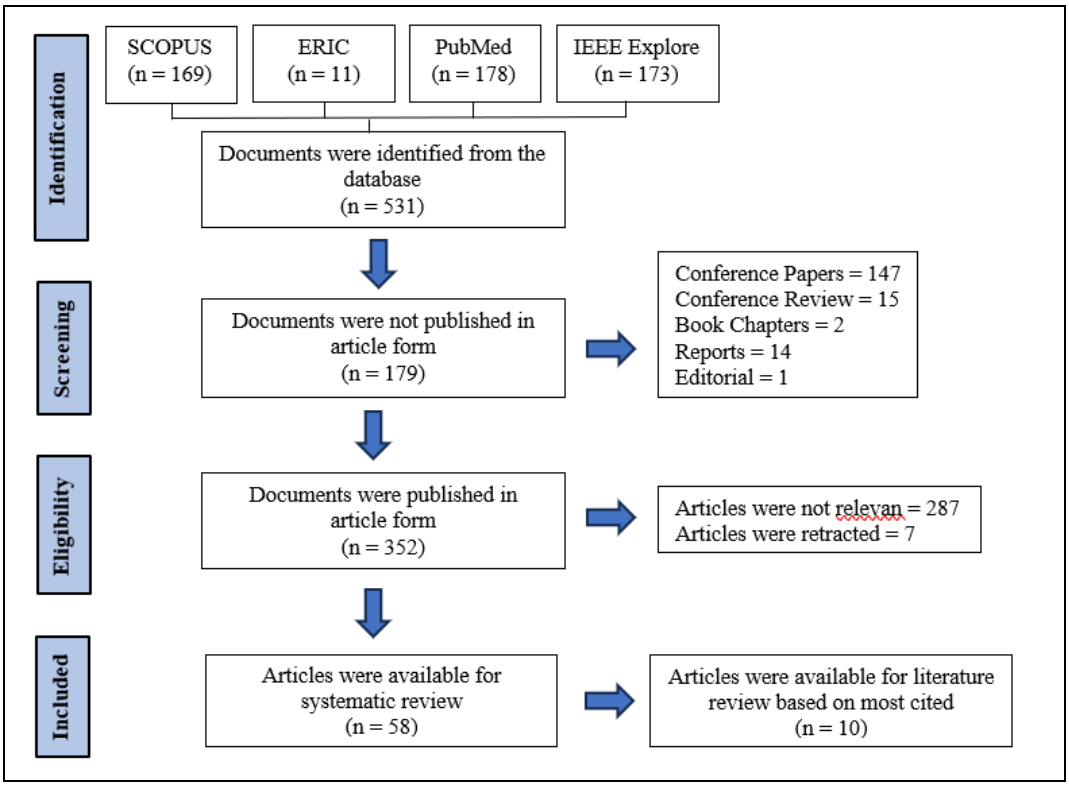

Figure 1. Research data screening process

Table 1. Research databases of deep learning in physical education

Source	Paper	Cites	Cites/Year	H-Index
SCOPUS	169	655	43.67	11
ERIC	11	4	0.40	1
PubMed	178	80	11.43	4
IEEE Xplore	173	186	26.57	2
Total	531	925	82.07	18

Research publication and development of deep learning in physical education

The development of Deep Learning (DL) research publications in Physical Education (PE) starting from 2010 until now continues to grow significantly and continuously (Figure 2). Based on statistical data from Table 2, at the beginning of its development year, the number of published research documents was only 6 (Table 2). Nevertheless, the research document contributed quite well by obtaining 179 citations, more than from 2011 to 2019. From 2020 to 2022, research development began to increase sharply, from 21 research documents published to 139 research documents. The total number of citations from these years is 508, indicating that DL research in PE experienced extraordinary development in these years. In those years, physical

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education experienced an evolution from a conventional educational process to a more modern one. However, this development became a turning point for a significant decline the following year, namely 2023.

The year 2023 became a moment of decline in the number of research publications and citations, with only 98 research documents successfully published and only 75 citations. However, this decline also became momentum the following year, and research development experienced fluctuations beyond previous years. One hundred seventy-one research documents were published in 2024, and the number of citations was still 53. The number of research documents in that year does not guarantee that the publication quality will also increase. The number of citations displayed is one indicator of the quality of the publication. This phenomenon can occur because there is a possibility that research in 2024 to 2025 is still developing, both in terms of citations and publications. The importance of the role of researchers in providing their best contribution to developing the science of physical education is key to developing research related to holistic physical education.

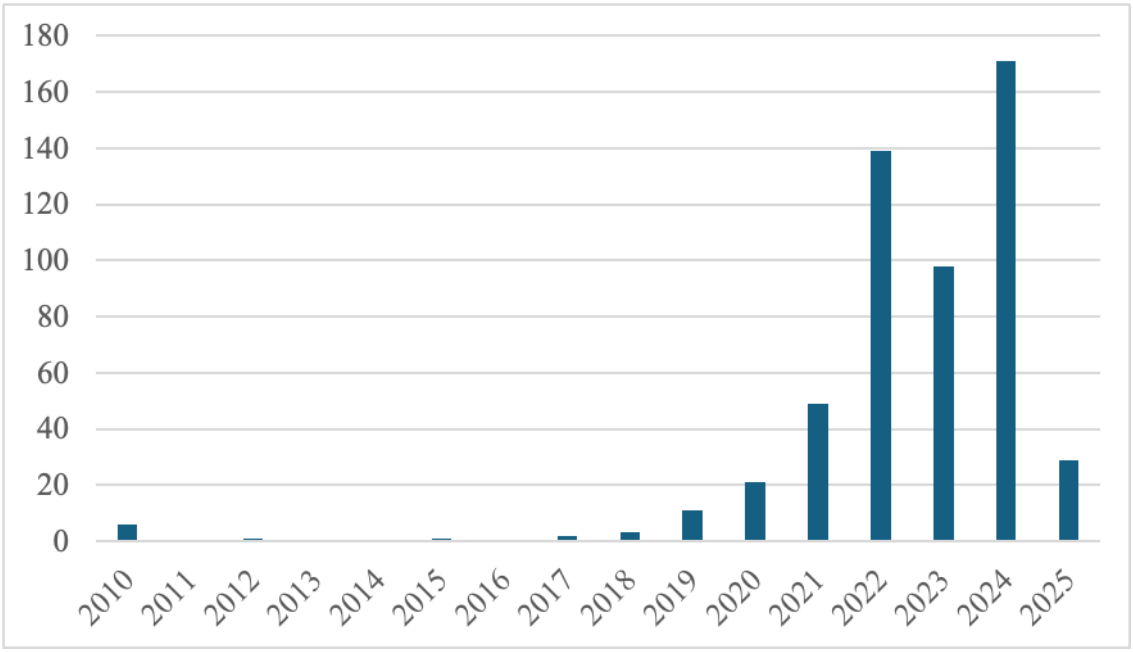

Figure 2. Research on the development of deep learning in physical education

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Table 2. Research publication of deep learning in physical education

Year of Publication	Paper	Cites	Average	Percentage (%)
2010	6	179	92.50	1.13
2011	0	0	0.00	0.00
2012	1	3	2.00	0.19
2013	0	0	0.00	0.00
2014	0	0	0.00	0.00
2015	1	0	0.50	0.19
2016	0	0	0.00	0.00
2017	2	11	6.50	0.38
2018	3	0	1.50	0.56
2019	11	88	49.50	2.07
2020	21	188	104.50	3.95
2021	49	124	86.50	9.23
2022	139	196	167.50	26.18
2023	98	75	86.50	18.46
2024	171	53	112.00	32.20
2025	29	8	18.50	5.46
Total	531	925	728.00	100.00

Research keywords analysis of deep learning in physical education

In this sub-section, the subject area sub-section, and the affiliation sub-section, researchers use the screening feature of the SCOPUS website. This is because only the SCOPUS website can screen these aspects. On the other hand, using one database will undoubtedly raise the possibility of bias and less comprehensive results. Nevertheless, researchers try to provide insight and an overview of the current state of Deep Learning (DL) research in Physical Education (PE) through SCOPUS as a reference. The SCOPUS database cannot represent the development of DL research in PE. Still, through a coherent and holistic discussion, it can become one of the references in developing future research.

The keywords shown in Table 3 are the top 10 keywords from the SCOPUS website screening results. These results indicate a correlation between physical education and the use of technology in the learning process. The emergence of the keywords “education computing” and “learning systems” proves that the physical education process cannot be separated from the involvement of technology. The

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keyword 'curricula' reflects how technology can play a role in the innovation and evolution of the education curriculum, especially in physical education.

Keyword analysis using VosViewer software was also conducted to provide a more comprehensive understanding. Based on the results of keyword analysis through the software, a visualisation of how DL research in PE develops by involving various aspects, especially technological aspects (Figure 3). In line with the data displayed in Figure 2, the research experienced a significant development between 2022 and 2025. The emergence of keywords "machine learning", "internet of things", "computer internet technology", and "algorithms" is an indication of the role of technology in changing the physical education process to be more modern or up-to-date. Keywords such as "innovative learning", "motion capture", and "biomechanical analysis" present the results of technology integration in the physical education learning process. In conventional learning, teachers provide direct feedback through narration and movement practice. Now, the technology learning process allows the evaluation process to be more holistic. In addition, the emergence of the keyword "artificial intelligence" means that the learning process has now involved Artificial Intelligence (AI) technology.

The involvement of AI in non-educational fields such as science and technology brings changes in efficiency and effectiveness. Its integration in the world of education, especially in physical education, will undoubtedly bring significant changes, making the learning process more interesting by adjusting the times. Collaborations between technology and physical education allow physical education teachers to provide a more innovative learning process so that students can enjoy an attractive and non-monotonous learning process.

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Table 3. Research keywords of deep learning in physical education

Keywords	*f*	Total cited	Average Cited
Deep Learning	86	246	166.00
Physical Education	76	478	277.00
Students	61	237	149.00
Teaching	33	68	50.50
Sports	33	107	70.00
Education Computing	27	89	58.00
Physical Education Teachings	24	83	53.50
Learning Systems	23	85	54.00
Human	17	73	45.00
Curricula	14	15	14.50
Total	394	1481	937.50

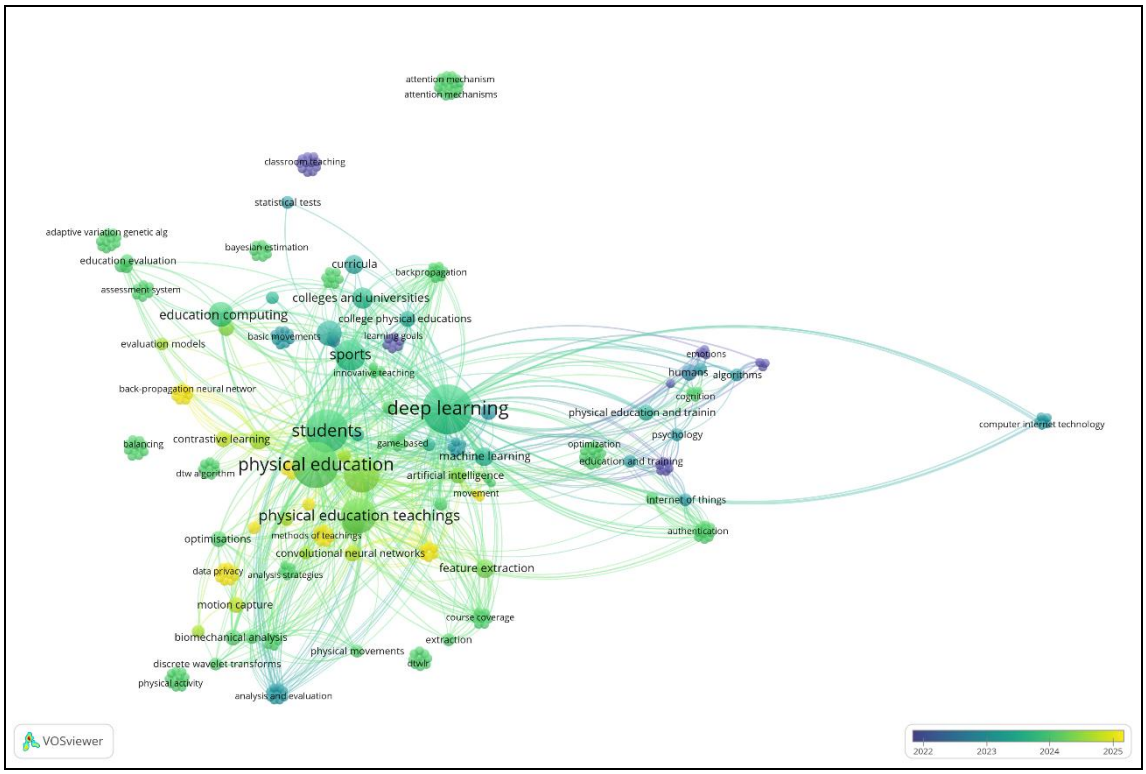

Figure 3. Keywords analysis of deep learning research in physical education

Research subject area of deep learning in physical education

The subject areas on Deep Learning (DL) research in Physical Education (PE) presented are the results of the top 10 subject areas screened through the SCOPUS website. These subject areas can be grouped into four aspects or sub-discussions: technology, cognitive, health, and multidisciplinary. Subject areas related to technology include “computer science”, “mathematics”, “engineering”, and “biochemistry, genetics

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and molecular biology". These subjects show how technological advances impact the learning process in physical education, with the emergence of new approaches such as deep learning. Learning that integrates technology allows the learning evaluation process to be maximized. Thus, the results can be linked to various academic and non-academic aspects.

The subject area relevant to cognitive aspects is "neuroscience". This subject area's emergence is evidence that DL research in PE cannot be separated from things that cover the mental domain. On the other hand, subject areas such as "social sciences" also have a relationship with cognitive aspects. The results of the thinking process that involves elements of neuroscience during the learning process can be shown through social science. This is because students cannot be separated from socially related things in learning physical education. At the same time, it triggers the level or condition of the mentality of the students as well, which eventually leads to the subject area "psychology".

The health aspect is also seen through the subject areas of "health professions" and "medicine," which shows that physical education connects with health aspects, such as fitness and injury. Physical education is about learning movement skills and how students keep their bodies healthy and fit. These efforts are made to prevent metabolic disorders; injury prevention will also indirectly correlate with this.

The subject area "multidisciplinary" is the last aspect that indicates that DL research in PE or during the physical education learning process involves various disciplines to create a holistic teaching and learning process. This modern approach, such as deep learning, allows aspects of physical education to be explored to the fullest. Integrating technology encourages a more innovative, attractive, and futuristic learning process. Other emerging subject areas illustrate how various disciplines contribute and collaborate on DL research in PE.

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Table 4. Research subject area of deep learning in physical education

Subject Area	*f*	Total cited	Average Cited
Computer Science	75	279	177.00
Mathematics	38	113	75.50
Engineering	32	79	55.50
Social Sciences	19	307	163.00
Neuroscience	14	43	28.50
Health Professions	13	193	103.00
Medicine	11	231	121.00
Biochemistry, Genetics and Molecular Biology	8	2	5.00
Psychology	6	51	28.50
Multidisciplinary	5	14	9.50
Total	221	1312	766.50

Research affiliation of deep learning in physical education

The development of Deep Learning (DL) research in Physical Education (PE) is inseparable from the contributions of various universities in various countries. The affiliation table (Table 5) presents how the top 10 universities, according to screening from the SCOPUS website, contribute to DL research in PE. If examined in detail, as many as five universities from China contributed 11 research document publications. In addition, in the mapping of country contributions in Figure 4, it is shown that China dominates DL research in PE with an extraordinary number of publications, namely 100 research documents (Figure 4). The data is evidence that in China, the learning process of physical education is considered through research in physical education, especially related to deep learning. China shows enthusiasm in improving the quality of physical education in the country. This extraordinary contribution is not only beneficial for China itself, but will provide insight and innovation for other countries. In addition, it will also encourage other countries to be more motivated to develop research related to DL in PE.

Other Asian countries such as Kazakhstan, Indonesia, Malaysia, Singapore, and South Korea also contributed to DL research in PE. Although the number of their publications is still not significant, this is evidence of how China encourages the surrounding countries to develop physical education through deep learning. Meanwhile, countries in Europe have not shown any considerable research development. This could

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be due to the different characteristics of European and Asian societies, causing the application of various learning approaches. There may be more suitable approaches than deep learning in physical education in these countries.

Table 5. Research Affiliation of Deep Learning in Physical Education

Affiliation	*f*	Total cited	Average Cited
Al Farabi Kazakh National University	4	18	11.00
Northeast Normal University	3	0	1.50
Akademia Wychowania Fizycznego i Sportu im. Jedrzeja Sniadeckiego w Gdansku	3	57	30.00
International University of Tourism and Hospitality	2	18	10.00
Northwest Normal University China	2	18	10.00
Kunsan National University	2	7	4.50
Universidad de Almería	2	36	19.00
Central South University	2	28	15.00
Zhengzhou University	2	57	29.50
Wenzhou University	2	3	2.50
Total	24	242	133.00

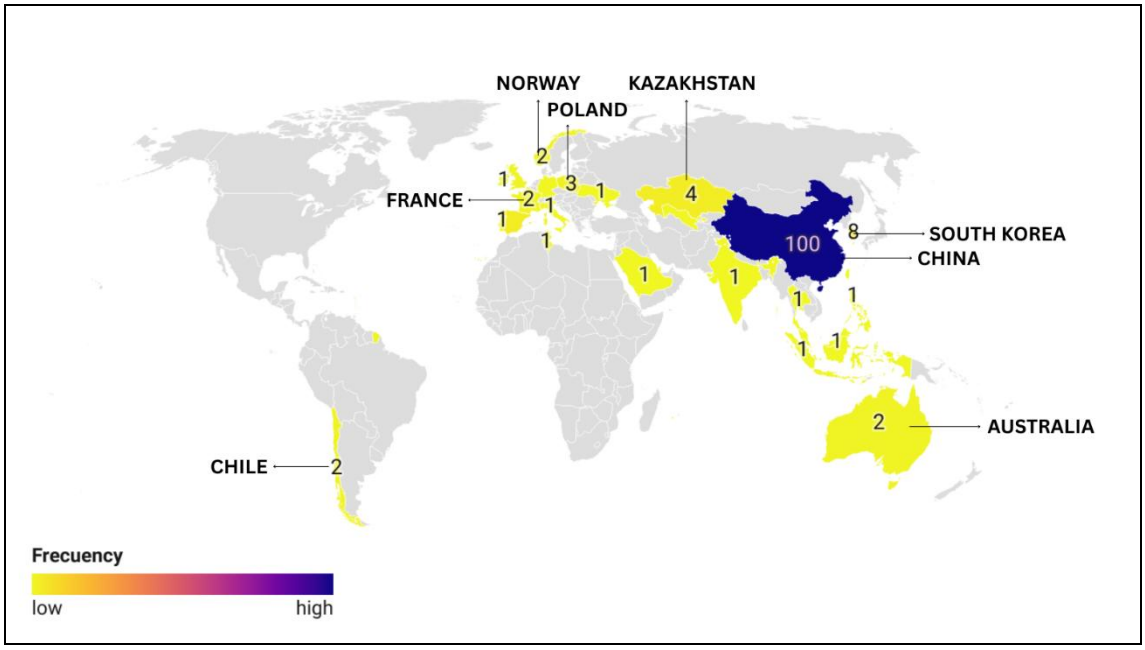

Figure 4. Countries contributed to deep learning research in physical education

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Literature review of deep learning research in physical education

The literature review in this study aims to provide a more in-depth overview of Deep Learning (DL) research in Physical Education (PE). Through the screening process adopted from PRISMA, the researcher seeks to provide transparency of the data collection process to obtain relevant and quality research documents. PoP software includes efficiently and effectively screening and selecting articles with the best citations for this sub-section's literature review. The screening process obtained 10 articles with the most citations and correlated discussions. Through these 10 articles, the research results can be discussed and linked to provide a holistic and comprehensive understanding.

Psychological and Cognitive Aspect

Research by Hu & Gao (2023) showed that implementing DL in PE learning effectively improves students' mentality and physique. In addition, by integrating psychology, Zong, Lipowski, Liu, Qiao, & Bo (2022) found that a DL-based psychology approach in PE effectively improves students' critical thinking and problem-solving skills. In line with this, Encinas, González, & García-Martín (2021) argue that it is essential to improve PE teachers' pedagogy through deepening their understanding of DL so that students can think critically. Yang, Xu, & Shu (2024) also proved that DL effectively improves students' thinking skills in PE learning.

Technological Integration Aspect

In order to support students' critical thinking processes, physical education teachers need to innovate their teaching methods in line with their students' characteristics. Therefore, research developments have begun to improve by incorporating the role of digital technology. According to Zhu, Xu, & Liu (2023), PE learning can be maximized very well through the flipped learning method integrated with music and DL. This certainly shows the transition of conventional learning methods into modern learning methods. According to Mou, Tian, Zhang, & Zhu (2022), modern learning methods that include elements of DL are considered very suitable for students in adjusting the PE learning process.

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Pedagogical Aspect

The involvement of technology in the physical education learning process requires teachers to be more professional. Physical education teachers need to align their pedagogical skills to be more creative and innovative based on modernization. Adjusting PE learning using technology can identify students' cognitive patterns, as in Zhao, Wu, Shao, & Ma (2024). Jiang, Du, & Zheng (2024), stated that modernization in PE can improve teachers' teaching competencies and provide more appropriate learning. The PE learning process that is feasible and suitable for students' needs must provide a good evaluation process. The role of DL in providing an in-depth evaluation of the PE learning process was effectively proven by (Wang, Yang, & Xing, 2022) and (Chen & Dong, 2022) through their research findings.

The findings of the previous studies prove the positive impact of implementing DL in PE. The learning process, which previously looked old-fashioned and inefficient, became more interesting due to the application of this DL approach. Aligning with the discussion in the previous sub-sections, DL cannot be separated from modern technology, such as AI, and modern technology related to DL. Such collaboration and integration in physical education will provide students with a feasible learning process. Students will be more motivated in learning because their environment influences the learning process in this digital era. However, the role of teachers in improving their pedagogy is vital to facilitate this dynamic learning process. PE teachers must be able to adapt and improvise from year to year, period to period, so that students can experience meaningful and quality PE learning.

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Table 6. Literature review of deep learning research in physical education

Author	Cited	Research Purposes	Study Design	Results
(Zong et al., 2022)	27	To improve significantly of the college physical education (PE) within the psychological development of PE students and to serve as a reference for the invention of PE pedagogical approaches.	Survey Study	In the domain of psychological quality assessment, the capacity for emotional regulation markedly enhanced, with the mean score rising from below 60 to above 79, including notable improvements in self-challenge capability and resilience to adversity. In the assessment of deep learning capabilities, pupils exhibited the most significant enhancement in critical thinking skills, but their sophisticated problem-solving abilities also showed some improvement.
(Zhu et al., 2023)	22	To investigate the efficacy of flipped classrooms augmented by music and deep learning in physical education for enhancing students' autonomous learning capabilities.	Experimental Study	The developed approach significantly enhances students' physical quality, motor skill proficiency, deep learning capacity, and autonomous learning capabilities in physical education, hence facilitating deep learning outcomes.
(Mou et	7	To employ	Comparative	The final comparison

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Review. Enhancing physical literacy in physical education: a systematic review of deep learning approaches. Vol. 12, n. º 2; p. 1-38, April 2026. https://doi.org/10.17979/sportis.2026.12.2.12325

Author	Cited	Research Purposes	Study Design	Results
al., 2022)		information technology to enhance the conventional teaching methodology and elevate the quality of physical education.	Study	results indicate that adaptive learning and deep learning models are more effectively tailored to students' learning regarding exam difficulty and accuracy than alternative methods.
(Encinas et al., 2021)	6	To investigate educators' attitudes regarding the promotion and instruction of critical thinking in Physical Education within Primary Education.	Semi-Structured Interviews	Although teachers consider it essential to develop pupils' cognitive skills in physical education, this is often undervalued due to the negative legacy of the discipline, inadequate teacher training, and teacher insecurity, with the majority also reporting unfamiliarity with the visual thinking and deep learning approach.
(Wang et al., 2022)	5	A deep learning-based evaluation method for assessing the quality of physical education teaching and training is proposed to address the challenges of significant difficulty and low accuracy in evaluating teaching outcomes.	Qualitative Study	The correlation coefficient between the evaluation findings and the actual outcomes is 0.9430, indicating an evaluation accuracy of 94.73%, hence demonstrating good reliability of the evaluation results. This study demonstrates that the deep learning-based teaching quality

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Author	Cited	Research Purposes	Study Design	Results
				evaluation method is both effective and practicable.
(Chen & Dong, 2022)	4	This paper highlights the inadequacy of the assessment and evaluation of traditional physical education professional skills courses and proposes a method for assessment and evaluation utilizing convolutional neural networks and small sample learning.	Experimental Study	Physical education teachers must genuinely transform their knowledge of professional skills and evaluation through the implementation of improvement strategies within the deep learning teaching framework. The method that was developed execute efficiently the strategies enhancement, advance the development of physical education expertise, and facilitate the transfer and innovation of sports knowledge and abilities.
(Jiang et al., 2024)	3	To enhance the efficacy of physical education (PE) instruction using deep learning (DL) for the superior development of high-caliber college students.	Comprehensive Analysis	The implementation of the Genetic Algorithm - Back Propagation - Random Forest algorithm to enhance the effectiveness of physical education lessons is viable. The proposed approach offers strategies for utilizing deep learning technologies to

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Author	Cited	Research Purposes	Study Design	Results
				enhance educators' instructional competencies.
(Yang et al., 2024)	1	To examine the implementation of deep learning in collegiate physical education, offering a novel pedagogical approach that markedly enhances results by cultivating students' practical abilities and creativity.	Experimental Study	The deep learning-based pedagogical approach in collegiate physical education can significantly enhance teaching quality and students' overall literacy, offering innovative concepts and methodologies for the reform of college physical education instruction.
(S. Hu & Gao, 2023)	1	To improve students mental and skills in physical education lessons combined with deep learning.	Experimental Study	The integration of physical education lessons with deep learning substantially enhances both the physical and mental health of individuals.
(Zhao et al., 2024)	1	To enhance students' comprehension of physical education teaching concepts and assist teachers in analyzing students' cognitive patterns by employing deep learning algorithms.	Experimental Study	The research demonstrates that the suggested model exhibits excellent accuracy and stability in predicting cognitive patterns, hence enhancing the identification of students' cognitive states and offering robust support for instructional assistance and tailored learning.

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Discussion

Physical Education (PE) has evolved its learning process through the evolution of its learning approach. The emergence of the Deep Learning (DL) approach in the PE learning process brings various latest and newest learning innovations. Various studies related to DL in PE have proven the strategy's effectiveness. Starting from the integration of technology involved, more effective and efficient learning adjustments, to the maximized assessment and evaluation process. This research aims to explore the impact of the implementation of DL in PE on modern technology. The results of this study obtained findings that are highlighted in several sub-discussions.

Deep learning as a pedagogical paradigm shift in physical education

Integrating Deep Learning (DL) into Physical Education (PE) signifies a radical shift in pedagogical philosophy, moving beyond traditional models of rote skill acquisition toward a more holistic, student-centered framework. Talaghir et al., (2020) found that traditional PE models tend to prioritize motor skill mastery over cognitive development, thereby limiting critical thinking opportunities. This approach, rooted in behaviorist theories, often neglects cognitive and affective dimensions of learning. On the other hand, DL prioritizes developing higher-order thinking skills (HOTS) like critical thinking, problem-solving, and reflective analysis, marking a significant departure from surface learning paradigms (Zong et al., 2022).

DL in PE aligns closely with constructivist and experiential learning theories, which suggest that learners build knowledge actively through experience and reflection (Shah, 2019). Theoretical underpinnings such as Vygotsky's Zone of Proximal Development (ZPD), Piaget's constructivism, and Bruner's spiral curriculum offer a foundational basis for understanding how DL can be implemented effectively in PE (Blake & Pope, 2008; Prakash Chand, 2023). For instance, DL encourages scaffolding, where educators guide students to stretch their current skill levels through guided discovery, collaborative learning, and meaningful reflection (McKee et al., 2023). This approach promotes a deeper engagement with content as students are encouraged to perform, understand, analyze, and evaluate their actions.

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Research by Zhaoyuan & Bingbing, (2023), explains that through the DL approach, PE learning can improve students' cognitive abilities (e.g., inquiry and exploration). This study proves that the implementation of the DL approach in PE learning involves problem-solving processes. Problem-solving skills are crucial in the PE learning process, students must devise strategies in team sports, analyze their physical performance using feedback tools, or reflect on exercise's physiological and psychological effects. Unlike conventional PE sessions, where drills dominate the instructional time, DL-infused lessons allow questioning, discussion, and self-assessment (Zhu et al., 2023). Students are no longer passive recipients of knowledge but active participants in a dynamic learning process.

Moreover, DL supports interdisciplinary integration, where PE is no longer an isolated subject but a platform for exploring broader educational themes (Hu Nvying, 2024). For example, concepts from biology (such as muscular systems or energy metabolism) (Pomeshchikova et al., 2016), psychology (motivation and emotional regulation) (Cassani et al., 2019), and mathematics (mathematical learning approach) (Lopatiev et al., 2017), can be embedded into PE sessions, enriching the learning experience and reinforcing connections across subjects. This approach nurtures a more comprehensive educational experience that addresses physical, cognitive, and emotional development.

The emphasis on joyful and meaningful learning within the DL model also transforms student motivation (Alnasyan et al., 2024). When learners find relevance and personal significance in their actions, this emotional connection is crucial in PE, where students' attitudes toward physical activity can have lifelong implications. DL encourages students to take ownership of their learning by fostering a sense of agency and purpose, enhancing intrinsic motivation, and long-term commitment to physical health. Through these aspects, students' physical literacy levels will be optimized. Students will have a high awareness of performing physical activities to support their health and fitness. The physical literacy acquired by students will become a foundation for promoting physical activity throughout their lives (Lynch & Soukup, 2016).

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Importantly, DL in PE supports diverse learning styles and abilities (Mou et al., 2022). Traditional PE often favors athletically inclined students, inadvertently marginalizing those who may struggle with physical tasks. DL, however, recognizes multiple intelligences and provides varied entry points for learning. Visual learners can benefit from video analysis, interpersonal learners from collaborative games, and reflective learners from journaling and self-assessment tasks. This inclusivity makes DL a powerful tool for equity in education.

The role of technology in facilitating deep learning in physical education

Integrating advanced technologies in Physical Education (PE) has opened new pathways for implementing dynamic, personalized, and data-driven deep learning (DL) pedagogies. While DL emphasizes meaningful engagement, critical thinking, and joy in learning, technology acts as the facilitator that brings these elements to life. From artificial intelligence (AI) to augmented reality (AR), these tools are transforming PE into an interactive, student-centered environment that supports individual growth and cognitive development (Calabuig-Moreno et al., 2020).

Artificial Intelligence (AI) is crucial in enhancing DL experiences in PE (Hu et al., 2024). Through AI-driven motion analysis, wearable sensors, and machine learning algorithms, educators can obtain real-time data on students' movements, biomechanics, and physiological responses (Szulc et al., 2024; Zhou et al., 2023). This data is then used to provide immediate, personalized feedback, enabling students to adjust and improve their techniques. Such data-centric instruction moves beyond generalized coaching and allows for differentiated learning pathways tailored to each student's abilities and goals (N. Li & Xue, 2023).

Wearable fitness trackers and motion sensors are increasingly prevalent in PE settings (Fang, 2022). These devices monitor various health indicators such as heart rate, step count, burned calories, and stress levels. When combined with DL approaches, this information becomes more than a numerical output; it becomes a reflective tool for students. They can analyze their data, identify patterns, set goals, and evaluate their progress. This improves physical outcomes and encourages metacognitive skills such as self-regulation and strategic planning.

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Another emerging technological innovation is the use of Augmented Reality (AR) and Virtual Reality (VR) in PE (Hu, 2023; Pratama et al., 2022). These immersive technologies provide simulated environments where students can practice skills, learn game tactics, or experience physically challenging situations in a controlled setting. For example, VR can simulate competitive game scenarios requiring real-time decision-making, promoting tactical understanding and situational analysis. AR, on the other hand, can overlay instructional cues during physical tasks, aiding real-time skill acquisition.

Gamification is another effective technological strategy that supports DL in PE (Fernandez-Rio et al., 2020). By integrating game mechanics such as points, levels, and leaderboards, educators can make learning experiences more engaging and motivating. Significantly, when gamification is designed with DL principles, it moves beyond entertainment, fostering strategic thinking, collaboration, and perseverance. Students are encouraged to reflect on their performance, learn from failures, and adapt their approaches to meet challenges.

Technology also enables flipped classroom models in PE (Huang & Yu, 2022). Students access instructional videos or simulations before class in this format, allowing for more active, participatory learning during PE sessions. This approach maximizes class time for hands-on practice and promotes deeper cognitive engagement as students come prepared with prior knowledge and questions. Additionally, online platforms and apps facilitate self-paced learning, where students can revisit content, complete assessments, and track their progress independently (R. Fang et al., 2022).

The integration of technological advances in physical education through the DL approach has had an impact on more innovative and attractive learning designs. This study has successfully proven the integration of technological innovations, ranging from digital devices to learning innovations involving AI. These developments have brought about changes in PE learning designs, making them more futuristic. Adjustments made in line with the times or in harmony with the digital age of the 21st century have resulted in optimalization student learning outcomes. Teachers and students are facilitated in the learning process through the efficiency of this technological advancement. This convenience also has another impact, namely an increase in students'

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physical literacy (Martín-Rodríguez & Madrigal-Cerezo, 2025). This is possible because, through more modern learning media, students are able to adapt more quickly. The clarity of the narrative packaged in the form of visual innovations makes students more prepared to receive learning materials. Thus, through the learning comfort felt by students, the PE learning process will be more optimal and meaningful. In addition, physical literacy, which can sometimes be a barrier to learning, can be minimized through innovations in learning media in PE.

Teacher readiness and professional development for deep learning in physical education

The successful integration of Deep Learning (DL) into Physical Education (PE) hinges not only on innovative pedagogy and emerging technologies but also, perhaps most critically, on the readiness and capability of teachers (Jiang et al., 2024). Educators serve as the architects of classroom transformation, and without their active engagement, DL cannot be sustainably or meaningfully implemented. Teacher readiness, professional development, and institutional support are fundamental pillars for advancing DL in PE.

Many PE teachers are deeply rooted in traditional, performance-based teaching methods focused on skill repetition, direct instruction, and physical assessment. While effective in specific contexts, these methods may limit opportunities for critical thinking, inquiry, and reflection, core components of the DL approach. Therefore, transitioning to a DL framework demands a pedagogical mindset shift, in which teachers redefine their role from authoritative instructor to learning facilitator (Darling-Hammond et al., 2024; Machost & Stains, 2023). This shift requires not only awareness but also a deliberate cultivation of new instructional competencies.

One significant barrier to this transformation is the lack of pre-service and in-service training programs that adequately prepare PE teachers for DL-oriented practices (Fletcher et al., 2019). Most teacher education curricula still prioritize foundational knowledge in kinesiology, sport science, and classroom management, while giving limited attention to cognitive engagement strategies, technology integration, and reflective teaching. Professional Development (PD) must fill this gap by offering

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practical, ongoing, and context-sensitive learning opportunities that empower teachers to explore and implement DL principles.

Effective PD programs should be grounded in active learning, just as DL emphasizes. Workshops, micro-teaching sessions, peer observation, and collaborative lesson planning allow educators to experience DL from the learner's perspective (Jones, 2022). Such programs can include action research projects where teachers design and trial DL-infused PE lessons, collect data on student outcomes, and reflect on their instructional practices. These activities promote a culture of inquiry, experimentation, and continuous improvement.

Mentorship and professional learning communities (PLCs) are also essential for fostering teacher readiness (Nemiña, 2018). New or hesitant educators benefit from the guidance of experienced peers who have successfully implemented DL strategies. Teachers can build collective expertise and confidence in designing cognitively rich and student-centered PE experiences through regular dialogue and shared practice.

Moreover, technology-specific training is vital. Teachers must be competent in using tools such as AI-based assessment apps, wearable fitness trackers, AR/VR simulations, and digital learning platforms. More importantly, they need to understand how to integrate these tools meaningfully into pedagogy, ensuring that technology serves learning goals rather than distracting from them. PD must go beyond technical skills to include pedagogical technology integration, commonly called Technological Pedagogical Content Knowledge (TPACK) (Cengiz, 2015; Mödinger et al., 2023).

Institutional support plays a decisive role in enabling or constraining teacher readiness. School leaders and education policymakers must create environments where innovation is encouraged and resourced. This includes allocating time for professional learning, providing access to necessary technologies, and establishing policies prioritizing student-centered, inquiry-based instruction. Recognition and reward systems for innovative teaching practices can motivate educators to embrace and sustain DL approaches.

Assessment practices should likewise be reformed to align with DL objectives. Traditional PE assessments often rely on physical performance metrics, which may not capture students' cognitive or emotional growth. Teachers need training and tools to

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assess critical thinking, collaboration, self-regulation, and metacognition, which are core outcomes of DL. Portfolio assessments, reflective journals, peer evaluations, and digital learning analytics can offer more holistic insights into student development.

Toward an inclusive future: addressing barriers and scaling deep learning in physical education

While the promise of Deep Learning (DL) in Physical Education (PE) is substantial, its realization must be anchored in equity and inclusivity (Sánchez et al., 2025). Without careful consideration of the structural and contextual barriers across educational systems, DL risks becoming an innovation accessible only to privileged schools and learners. As such, efforts to scale DL in PE must intentionally address disparities in resources, training, and cultural relevance to ensure that all students benefit from cognitively enriching and meaningful physical education.

One of the most pressing challenges is the digital divide, which refers to unequal access to technology, internet connectivity, and digital literacy. In many under-resourced schools, particularly in rural or economically disadvantaged areas, even basic technological tools such as tablets, wearables, or internet access may be unavailable (Mustafa et al., 2024). For DL to thrive in such contexts, scalable and low-cost solutions must be developed. These could include offline-accessible resources, mobile-based learning tools, and community partnerships that provide shared access to equipment and facilities.

Another critical factor is curriculum flexibility. Standardized curricula can constrain teachers' ability to experiment with DL approaches, especially if they are overly focused on physical performance benchmarks or rigid instructional sequences. District and national-level policy reforms are needed to embed DL principles such as inquiry-based learning, reflection, and critical thinking into official PE frameworks. DL transitions from an optional innovation to a systemic norm by integrating these elements into national curricula.

Cultural responsiveness is also key to inclusive DL. Cultural norms, values, and expectations profoundly shape PE practices and student experiences. A successful DL approach in one cultural context may not resonate in another. Therefore, DL

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implementation must be adapted to reflect local traditions, student backgrounds, and community priorities. This requires involving local stakeholders, such as students, parents, and community leaders, to co-create learning experiences that honor and build upon their lived realities.

Inclusion of students with disabilities is another vital dimension of equity in DL-based PE (Dubey, 2024; Song et al., 2024). Traditionally, students with physical, cognitive, or sensory impairments have been marginalized in PE programs. DL offers powerful opportunities to redesign instruction for these students through adaptive technologies, differentiated instruction, and Universal Design for Learning (UDL) principles. For example, AR tools can provide multimodal instructions, while AI-powered platforms can adjust task difficulty in real-time based on a student's needs. Teacher training must explicitly address inclusive strategies to ensure no learner is left behind.

Sustainable scaling of DL in PE also requires robust monitoring and evaluation (M&E) systems. Data on student engagement, learning outcomes, teacher readiness, and implementation fidelity should be collected and analyzed to inform continuous improvement. Governments, universities, and non-governmental organizations can collaborate to develop evidence-based models that guide DL adoption across diverse school settings. Research-practice partnerships can play a crucial role in this process.

Finally, global collaboration can accelerate the diffusion of DL innovations. Cross-country networks of educators, researchers, and policymakers can share best practices, tools, and findings to enhance collective capacity. Online repositories, webinars, and joint projects can foster a spirit of global learning while ensuring that local adaptations remain central to implementation.

Conclusion

Implementing the Deep Learning (DL) approach in Physical Education (PE) has been ongoing in recent years. This study successfully obtained several key findings that can be used as an evaluation for future research. The development results from year to year show a massive increase in publications in the last 5 years. The role of DL in bringing changes in a more holistic learning process is characterized by the involvement

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of various subject areas in previous studies. Technological advances such as Artificial Intelligence (AI) are one of the causes of the evolution of the learning process in PE. The development of AI in PE causes the efficiency and effectiveness of the learning process to be felt, both by teachers and students.

These findings indicate the presence of digitalization in the educational environment, particularly in physical education. The educational environment is one of the environments that has been affected by and has had an impact on this digitalization. Physical education has become more innovative, no longer focusing solely on conventional movement exploration. The role of teachers has been simplified and made more efficient through the integration of this technology. Students will also receive material better through clearer and more attractive visualizations.

On the other hand, the evolution of the learning process still requires optimization so that the implementation can be truly maximized and comprehensive. Increasing students' digital literacy is also needed to accept digitalization-based learning. In addition, PE teachers also need to develop their pedagogy to adjust the dynamics of the learning process. Thus, the teaching and learning process can be carried out with the objectives of the deep learning approach.

Previous researchers have successfully produced quality findings related to DL research in PE. However, many other aspects still need to be explored in future studies. Future studies need to pay more attention to how the DL approach compares with different learning approaches. In addition, it is essential to study at various school levels so that the level of effectiveness at each school level can be known. Through more massive and significant developments, research related to DL in PE will be optimized to provide references for physical education practitioners in delivering a more meaningful learning process.

Limitations and recommendations

Apart from the results and discussions presented coherently and comprehensively, this research has limitations that allow it to have some shortcomings and are needed for improvement in future research. One of the limitations of this study

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is that there are only four databases, allowing for incomplete or inappropriate identification results. Then, some sub-sections are only sourced from the SCOPUS website, allowing for incomplete data presentation. In addition, selecting articles for the literature review, which is only based on the most citations, does not necessarily mean that the article is of good quality. The number of citations generated may occur due to self-citation.

The solution that researchers can offer to resolve some of these limitations is to add a database so that research results can be more complete, and more relevant research can be obtained. Furthermore, optimizing and developing features on the database or journal pages are needed to facilitate researchers in screening research documents. Providing a screening facility similar to the SCOPUS website will be very beneficial for systematic review research when the data identification process is carried out. Finally, a rating or open assessment of an article may be applied, so that when researchers want to know the quality of a study, it can be reviewed based on the rating results. On the other hand, it will give a study a validity value through the rating and reliability through the citations displayed.

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