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# Mapping the Landscape of Deep Learning in Meaningful Principles: A Decade-Long Bibliometric Review (2015–2025)

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**Abstract:** This study aims to explore how Deep Learning (DL) contributes to meaningful learning in response to the increasing demand for ethical, transparent, and student-centered applications of Artificial Intelligence (AI) in education. The study employs a bibliometric analysis of 110 Scopus-indexed publications published between 2015 and 2025, using Biblioshiny in the R Bibliometrix package to identify research trends, key contributors, institutional productivity, and thematic developments. The analysis encompasses publication trends, citation patterns, author and country productivity, collaboration networks, and keyword co-occurrence. The findings indicate that, although the majority of studies originate from computer science and engineering, there has been a growing shift toward education and the social sciences, reflecting an increasingly interdisciplinary orientation, particularly after 2020. Emerging themes such as explainable AI, adaptive learning, and ethical AI suggest a transition from technology-driven innovation toward pedagogy-oriented and ethically grounded practices. Keyword co-occurrence analysis reveals three dominant thematic clusters: (1) explainable AI in pedagogy, (2) adaptive learning systems, and (3) ethical and human-centered AI in education. This shift reflects a broader movement toward human-centered AI that enhances learning relevance, personalization, and engagement. Overall, the integration of DL in education is evolving beyond technical efficiency to support meaningful, ethical, and learner-centered educational experiences.

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## Introduction

Deep learning (DL) has increasingly been applied in educational technology to support adaptive learning systems, learning analytics, and intelligent tutoring systems. These developments create new opportunities for improving personalized learning and student engagement. (Yang et al., 2022). In recent years, the number of publications related to deep learning has increased significantly, reflecting growing global interest in the use of artificial intelligence (AI) for digital transformation in education. However, despite this rapid development, concerns remain regarding the lack of transparency, interpretability, and human-centered principles in many AI-based educational systems. (Zawacki-Richter et al., 2020)

The integration of meaningful learning principles with AI technologies is also aligned with Sustainable Development Goal (SDG) 4, which promotes inclusive and equitable quality education. Previous studies show that deep learning models can support predictive learning analytics, enabling educators to identify students at risk of academic failure and improve adaptive learning strategies (Emirtekin, 2024). (Bakyalakshmi, 2024), Furthermore, the

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combination of learning analytics and deep learning can enhance reflective learning and personalized learning experiences (Alenezi, 2024). In educational contexts, deep learning approaches encourage active engagement, critical thinking, and learner-centered instruction that supports deeper understanding and meaningful learning processes (Kewalramani et al., 2024; Warman et al., 2025) (Khasanah & Al Majid, 2025).

The integration of meaningful learning principles with artificial intelligence technologies is also aligned with Sustainable Development Goal (SDG) 4, which emphasizes inclusive and equitable quality education. The use of meaningful learning approaches supported by AI has the potential to improve learning effectiveness while promoting fairness, transparency, and ethical educational practices. (Fang et al., 2023) (Gonzalez & Torres, 2022) However, existing studies largely focus on the technical development of artificial intelligence in education, with limited attention to how deep learning research evolves in relation to meaningful learning principles. Therefore, this study provides a bibliometric perspective to systematically map research trends, thematic developments, and interdisciplinary connections between deep learning and meaningful learning in educational contexts. By identifying emerging themes and research patterns, this study contributes to a deeper understanding of how AI-driven educational technologies can support more human-centered, ethical, and meaningful learning environments.

Recent literature indicates that the focus of deep learning research is gradually shifting from purely improving computational accuracy toward developing explainable and interpretable AI systems. (Zhang et al., 2024). In educational contexts, this shift is particularly important because the use of non-transparent models may lead to algorithmic bias and reduced trust in AI-supported learning environments. However, previous studies suggest that research on deep learning in education remains fragmented and has not yet been systematically mapped in relation to meaningful learning principles (Murtonen et al., 2024). Consequently, a comprehensive analysis is needed to understand how this research area has evolved over time.

Based on this research gap, this study aims to explore the development of research on deep learning approaches in relation to meaningful learning principles. Specifically, this study addresses the following research questions: (1) How have publication trends on deep learning approaches related to meaningful learning developed from 2015 to 2025?, (2) Who are the most productive authors, institutions, and countries in this research field?, (3) What are the major research themes and emerging topics in meaningful deep learning research?, (4) What research gaps and future directions can be identified from the bibliometric mapping?

To answer these questions, this study conducts a bibliometric analysis of Scopus-indexed publications published between 2015 and 2025. The analysis aims to identify publication trends, collaboration patterns, and thematic developments in research related to deep learning and meaningful learning principles. The findings are expected to contribute to the academic literature by providing a comprehensive overview of this research field and identifying potential directions for future studies. In addition, the results may offer insights for researchers, educators, and policymakers in developing more ethical, inclusive, and human-centered AI applications in education.

 

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## Research Method

This research employs bibliometric methods. Bibliometric analysis is a quantitative way of documenting trends in the academic literature (Kurdi & Kurdi, 2021). Using Scopus data (Mubarrok & Rahmawati, 2020), the method can also be used to map research trends, collaboration networks, and geographical contributions (Fikri, 2024; Nainggolan et al., 2024) (Aryadi et al., 2025). The study used Biblioshiny, the web interface of the Bibliometrix R-package, to perform bibliometric data analysis and visualization. Data analysis was conducted using R version 4.5.1 and the Bibliometrix R-package via the Biblioshiny interface. hile the research of (Solikah et al., 2025) employed VOSviewer for visualization of citation networks and keywords as well. Bibliometric analysis is currently utilized to evaluate scientific publications in a thematic area. To monitor the direction of research development and trending/ubiquitous terminology or notions frequently discussed within the evaluated publication (Astuti Iriyani et al., 2023) (Khumayroh & Lismawati, 2025). The study resents the method of analysis employed to review articles published on this issue, which allowed data collection and analysis to be conducted in support of trends on the assessment of teacher performance and decision-making (Turner et al., 2024) (Insan & Waluyo, 2025).

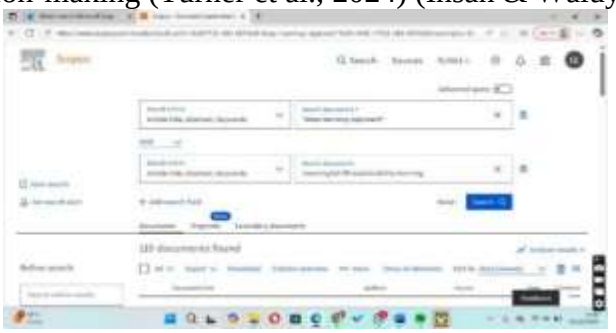

**Figure 1. Metadata Mining Results on Scopus database**

( TITLE-ABS-KEY ( "deep learning approach" ) AND TITLE-ABS-KEY (meaningful OR explainability learning ) ) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND ( LIMIT-TO ( SUBJAREA , "COMP" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) OR LIMIT-TO ( SUBJAREA , "SOCI" ) ) AND ( LIMIT-TO ( EXACTKEYWORD , "Deep Learning" ) OR LIMIT-TO ( EXACTKEYWORD , "Learning Approach" ) OR LIMIT-TO ( EXACTKEYWORD , "Explainable Deep Learning" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO ( OA , "all" ) )

This query yielded 110 documents deemed most relevant. This two-stage strategy was implemented to broadly map the research landscape and focus on publications directly related to deep learning approaches in the principles of meaningful and explainable learning (Moral-Muñoz et al., 2020; Xu et al., 2023). All data were then exported in CSV format from Scopus and analyzed using Biblioshiny, a web-based interface of the bibliometrix package in R, specifically designed for interactive bibliometric analysis (Aria & Cuccurullo, 2017; Moral-Muñoz et al., 2020). The analysis phase encompasses several key dimensions. First, publication and citation trends were analyzed to map research dynamics during the 2015–2025 period. Second, authors, institutions, and countries were analyzed to identify the most productive actors and patterns of global scientific collaboration (Chen et al., 2021; Wang et al., 2020).

The following process was a journal mapping that focused on the most productive publication channels through article counts, h-index ranking, and total citations. Meanwhile,

 

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the keyword analysis also investigated the development of research themes, topic distribution, and a new trend in meaningful deep learning. Next, relevant articles were screened for eligibility. The most influential papers and high-impact articles, thus offering an overview of the mainstream research output in this area. Finally, all of these discussions were synthesized to form a set of research gaps, the under-explored areas that the community should make progress on, thereby contributing both conceptually and practically to building deep learning models that are meaningful, explicable, and human-oriented (Zhang et al., 2024) (Liu et al., 2023).

## Results and Discussion

### Global Landscape of Deep Learning Research Based on Meaningful Principles (2015–2025)

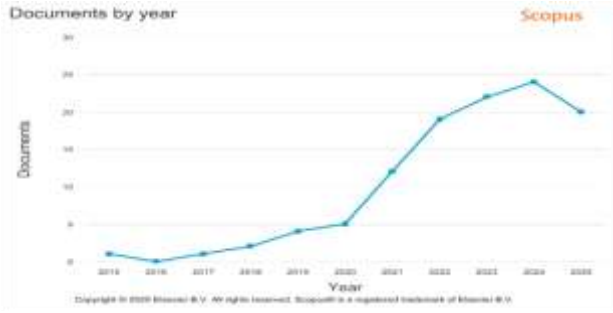


**Figure 2. Publication Development 2015-2025**

The publication dynamics in Figure 2 demonstrate a dramatic explosion in 2018, indicating a great redirection from algorithmic applications to injecting more meaningful human values into deep learning-based education. This greater productivity is in accordance with the conclusion of (Yang et al., 2022) and (Jin et al., 2023), noting that progress in AI technologies is inspiring new approaches to education with human-focused accents (human-centered AI). This suggests a departure from concern with computational efficiency and towards pedagogy. Nevertheless, the findings of this study do not agree with those of (Zhao et al., 2022) This contrast is natural since education, at this time, has entered the conceptualization level regarding deep learning.

### The Most Dominant and Influential Journals in Publication

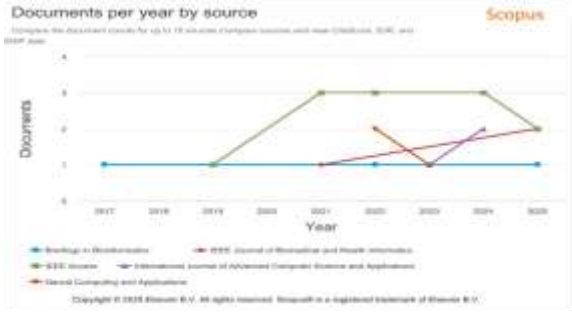


**Figure 3. Main Journal**

For the period 2020–2024, IEEE Access was the leading contributor to Deep Learning Approaches towards Meaningful Principles, while the remaining authors were Briefings in Bioinformatics, Neural Computing and Applications, International Journal of Advanced Computer Science and Applications, and IEEE Journal of Biomedical and Health Informatics. The predominance of these journals indicates a narrative that deep learning research remains better informed by engineering and computer science than it is budgeted in education,

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adaptive focused matter. (Yang et al., 2022) (Li et al., 2023). This supports the idea that it is possible to predict and encode human behavior patterns using machine learning techniques, not only in a clinical but also in an educational setting. (Darroudi et al., 2021).

**Contributions of Countries, Institutions, and Main Author**


**Figure 4. Country Contribution**

The chart entitled "Documents by Country or Territory" shows that the United States, China, and India are the leading contributors to publications on deep learning approaches in meaningful learning principles (Scopus, 2015–2025). The dominance of the United States can be attributed to its strong research ecosystem in educational technology, particularly in areas such as learning analytics, intelligent tutoring systems, and automated assessment, supported by national initiatives and policies from institutions such as the U.S. Department of Education (U.S. Department of Education, 2023).

China's significant contribution is closely linked to its large-scale national investment in Artificial Intelligence in Education (AIEd), which promotes the development of AI-driven personalized learning systems and large-scale online learning platforms, including MOOCs (Tzeng, 2022). These initiatives reflect China's strategic policy to integrate AI technologies into its national education system. Meanwhile, India demonstrates strong growth in educational technology research and student performance analytics, reflecting the increasing adoption of AI-based adaptive learning solutions in countries with large and diverse student populations. This trend is also supported by the rapid expansion of digital education infrastructure and government initiatives aimed at improving access to technology-enhanced learning (Kabudi, 2021).

From a broader perspective, these patterns highlight how national policies, technological investments, and educational priorities shape the global distribution of research contributions in the field of AI-supported meaningful learning.

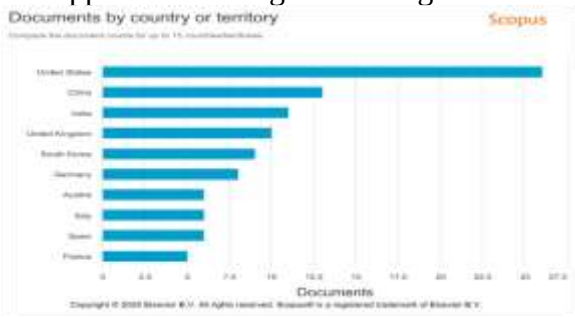


**Figure 5. Country Collaboration**

The results of the Country Collaboration Map indicate that the US is at the centre of the global collaborative network for Deep Learning Approach in Meaningful Principles research from 2015-2025, followed by China, India, the UK, Germany, and South Korea. These findings are in accordance with (Hu et al., 2020) U.S.–Asia collaboration has seen the

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application of AIED in personalized learning as a key research area, while U.S.-Europe synergy is strong in terms of studying the ethics and transparency of algorithms (Anisaturrizqi & Yulianti, 2025).This is also in line with the study by (Zulfikasari et al., 2025) and (Rahman & al., 2024), who emphasised the rise of interdisciplinary work between disciplines.

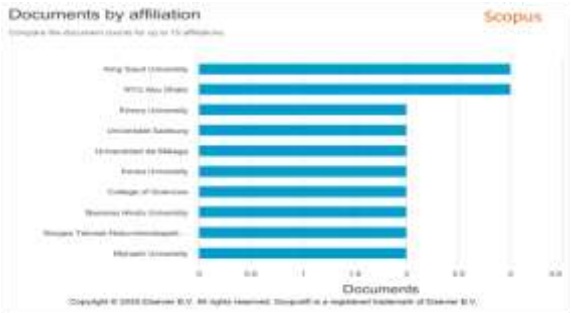


**Figure 6. Institutional Contribution**

Breaking down further, 'Deep Learning Approaches in Meaningful Principles – 2015–2025' by Documents by Affiliation, King Saud University, and NYU Abu Dhabi were the top two leading institutions. Emory University, the Universität Salzburg, and the Universidad de Málaga also came close behind. This observation is in accordance with those of Hu et al. (2020) and (Mayasari et al., 2024), who reported a rise in educational cooperations and digitization of education in the Eastern Mediterranean and Asia. In addition, the research focus that combines deep learning, learning analytics, and educational psychology is also consistent with (Durak et al., 2024) This study challenged the underlying trend from predominantly US and Europe-based researchers by presenting a more balanced level of contributions from around the world.

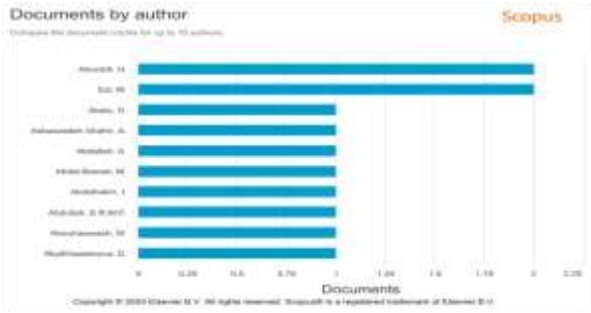


**Figure 7. Author Contribution**

The Documents by Author chart indicates that some publications are published by Alsuradi, H., and Eid, M. as the top authors in the Deep Learning Approach in Meaningful Principles topic, focusing on adaptive learning, learning analytics, and intelligent learning systems. This result is in accordance with the studies of (Durak et al., 2024) and (Mayasari et al., 2024) (Zulfikasari et al., 2025) For example, Rajabalee and Santally (2023) stress that educational AI is finally moving decisively towards systems that guarantee traceability and accountability for decision-making. Similarly, (UNESCO, 2024) the increasing input from researchers in Asia and Middle Eastern states significantly contributes to fostering inclusive and human-centric AI views at the international level.

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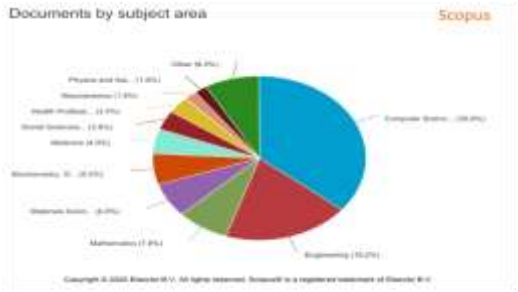


**Figure 8. Field of Study**

The study fields distribution diagram indicates that the field of Deep Learning Approaches in Meaningful Principles research still mainly centers on Computer Science (34.7%) and Engineering (20.5%); however, Education (9.6%) and Social Sciences(6.2%) have been significantly increasing. This trend is consistent with the results from Hu et al. (2020) and Durak et al. (2024), who noted that in the beginning, AI research was centred on technical aspects, but later turned into pedagogical and social applications. (Anisaturrizqi & Yulianti, 2025) and (Mayasari et al., 2024) Recent bibliometric analyses also demonstrate that this disciplinary boundary crossing is going further still, as researchers increasingly adopt integrative frameworks which combine data-driven modelling with theories of cognition, motivation, and socio-cultural learning (Schneider & Kizilcec, 2023) and (Akgun & Greenhow, 2024).

**Most Frequently Cited Articles or Literature**

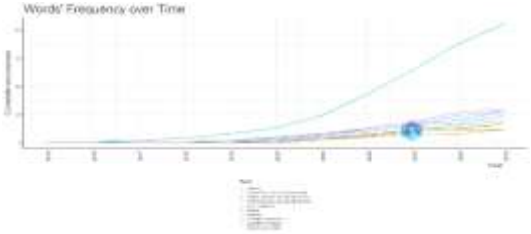


**Figure 9. Most Globally Cited**

Research on the Deep Learning Approach in Meaningful Principles is closely concentrated in the technical literature, where Briefings in Bioinformatics (2017) is characterized as a core reference with 2,160 citations. The pervasiveness of such a rule clearly suggests that the methodology to teach and learn based on deep learning mainly borrows models and algorithms from bioinformatics and high-performance computing. This observed trend is consistent with the results of Hu et al. (2020) and Durak et al. (2024), which contend that the AI precursors in education research originate as a technical innovation before maturing into a pedagogical context. the research direction will now move to humanistic application — whereby a deep learning system is used to understand students' learning behavior, motivation, or cognitive reflection (Mayasari et al., 2024) and (Zulfikasari et al., 2025).

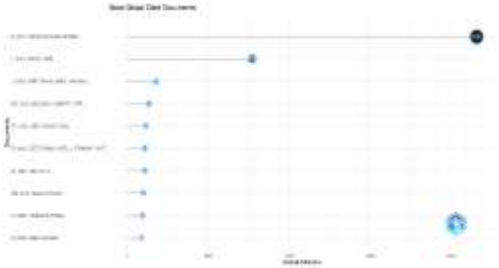

**Figure 10. Evolution of Keywords and Citation Bursts**

 

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Since 2020, there has been an explosion of interest in artificial intelligence and deep learning technology, as measured by the extraordinary surge in popularity for the terms ‘artificial intelligence’ and ‘deep learning’. This finding is in accordance with that of (Ling et al., 2023) and (Li et al., 2023) embedding deep learning into educational systems is not as simple as inserting new technology, but stems rather from a re-conceptualisation of how educational environments might be personalised in response to learners' behaviour and cognitive states, and evolving competencies towards meaningful and equitable learning. Following this trajectory, emphasis is now shifting to how institutional design, curriculum architecture, and assessment ecologies will need to evolve.

**The gap Knowledge (Research Gaps)**

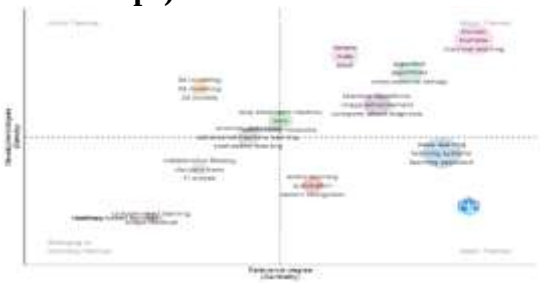

**Figure 11. Research Gaps**

The results also show that deep learning, learning systems, and machine learning are always among the focus topics of the next decade, 2015–2025, in both preliminary thematic map analysis and research trend analysis. Such a finding reflects the leading global literature direction where collaborative research on artificial intelligence is primarily concentrating on network model design and algorithm improvement. (Jin et al., 2023). But unlike other applied fields, which have developed integrative features—e.g., the interaction between technology and biological/clinical factors (Yang et al., 2022)—Deep learning research on meaningful learning is still in its infancy regarding the pedagogical and psychological aspects.

**The Relationship Between Research on Deep Learning Approaches and the Study of Meaningful Principles with Multidisciplinary Issue**

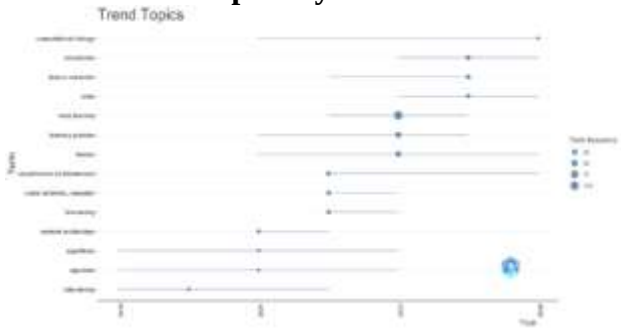


**Figure 12. Current and Future Topics**

The trend topics chart shows that terms such as “human,” “learning systems,” and “computational biology” increased significantly between 2020 and 2025. This development indicates a shift in research focus from system-centered approaches toward more human-centered perspectives in artificial intelligence research, emphasizing how deep learning models can support and replicate human learning processes. In educational contexts, human-centered AI aims to enhance personalized learning, adaptive instruction, and student engagement (Nations, n.d.)

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Meanwhile, the increasing attention to feature extraction and algorithmic techniques reflects the growing importance of improving model efficiency, interpretability, and transparency. These aspects are particularly important in educational environments, where explainable AI is needed to build trust among educators and learners and to ensure ethical AI implementation (Baker & Hawn, 2022). In addition, deep learning techniques are increasingly applied in learning analytics to generate data-driven insights into student learning processes (Siemens et al., 2023). These findings suggest that future research should further explore the integration of explainable and human-centered AI models to support more meaningful and ethically grounded educational technologies.

## Conclusion

The findings of the analysis reveal that research direction is still highly dominated by computer science and engineering, but is slowly shifting towards a multidisciplinary approach focusing on interpretation, ethics, and pedagogical relevance. Explainable AI, adaptive learning, and ethical AI are important nodes of the global education cooperation; however, studies in human motivation, cognition, and reflection processing are much less explored. These results suggest that the technical aspect and humanism as one will promote the situation for richer learning by means of deep learning. Hence, mixed methods research should also be used in future research with more emphasis on qualitative approaches that are able to study human agency and learning. This approach is important, as we need to develop more personalized, holistic, and sustainable deep learning systems, congruent with Sustainable Development Goal (SDG) 4 on quality education. There is additional evidence, coming from new research, that the trend towards a more human-centric embedding of AI technologies will give rise to interdisciplinary cooperation.

## Recommendation

Future research should shift from purely technical approaches to interdisciplinary collaboration that integrates computer science with pedagogy and psychology, focusing on developing explainable and human-centered AI models. Researchers must expand studies beyond dominant regions (US, China, India) to ensure equitable access in diverse contexts aligned with SDG 4 and SDG 10. Additionally, ethical frameworks and teacher AI literacy programs are essential to address barriers of model interpretability, algorithmic bias, and digital divide before widespread Deep Learning implementation in education.

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