Trends, Gaps, and Future Directions of Deep Learning in Education: A PRISMA-ScRGuided Scoping Review of Scopus Literature (2000-2025)

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Abstract: The rapid digital transformation of education has accelerated the use of artificial intelligence, particularly deep learning, to support adaptive and personalized learning systems. However, research in this field remains fragmented, and its overall development has not been systematically mapped. This study aims to identify trends, gaps, and future directions of deep learning in education between 2000 and 2025. A scoping review was conducted on 491 journal articles indexed in Scopus, followed by bibliometric analysis to examine publication growth, keyword co-occurrence, and thematic clusters. The results show a sharp increase in publications since 2018, reflecting growing academic attention to this field. Four dominant clusters were identified: (1) academic evaluation and assessment, (2) learner perceptions and experiences, (3) algorithmic exploration and model efficiency, and (4) reflective and systemic approaches to technology-based learning. While technical and evaluative studies dominate, ethical, affective, and social dimensions remain underexplored, particularly in primary education and Global South contexts. The findings highlight the need for future research to adopt a more transdisciplinary and contextualized approach, integrating pedagogy, digital ethics, and human-centered design. This study contributes strategically by providing a comprehensive knowledge map to guide researchers, policymakers, and practitioners in designing equitable and sustainable AI-based education systems.

Keywords: Deep Learning; Education; PRISMA-ScR; Scoping Review; Bibliometrics

Introduction

The transformation of education in the digital era has increasingly become a global agenda, driven by advances in artificial intelligence (AI) and machine learning (Cantú-Ortiz et al., 2020; Pedro et al., 2019). Among the various approaches, deep learning has emerged as a prominent technology with the capacity to process big data, recognize patterns, and generate adaptive predictive models. In the educational context, it not only automates aspects of the learning process but also offers transformative potential for pedagogy, curriculum design, and institutional decision-making (George, 2023; Zeide, 2017). This aligns with the broader visions of the Industrial Revolution 4.0 and Society 5.0, which emphasize personalized, inclusive, and learner-centered systems (Adel, 2024; Ahmad et al., 2023).

Despite this potential, the practical adoption of deep learning in education remains limited. Its applications are mostly concentrated in STEM disciplines and higher education, while primary and secondary education, as well as the humanities, have yet to benefit significantly (Bhutoria, 2022; Rane et al., 2023). Moreover, structural barriers such as data bias, unequal digital access, and limited educator competencies hinder equitable and ethical implementation (Bati & Workneh, 2021; Hew & Brush, 2007). These challenges reveal a persistent gap between the theoretical promise of deep learning and its actual integration into diverse educational practices.

Existing literature has grown rapidly in response to the digital transformation of education (Akour & Alenezi, 2022; Mohamed Hashim et al., 2022; Mukul & Büyüközkan, 2023). However, much of this research remains fragmented, technical, and focused on algorithmic accuracy, with insufficient attention to pedagogical, social, or policy dimensions (Fahd et al., 2022; Hamzah et al., 2024; Hu & Raman, 2024). Few studies have provided a systematic mapping of temporal trends, thematic developments, and future directions in the field. Addressing this gap is crucial to support both theoretical advancement and practical decision-making in AI-driven education.

The novelty of this study lies in its comprehensive mapping of deep learning research in education over the period 2000–2025, combining a scoping review approach with bibliometric analysis. Unlike earlier studies that narrowly assessed technical applications, this research integrates multiple perspectives to capture dominant trends, identify gaps, and project future trajectories. By doing so, it contributes not only to the academic knowledge base but also to policy design and educational practice, offering insights into how deep learning can be ethically and inclusively integrated into diverse learning environments.

Accordingly, this study has three main objectives: to identify dominant trends in deep learning research in education, to map thematic, methodological, and geographical gaps in the literature, and to project future research directions through visual and chronological synthesis of bibliometric data. To achieve these goals, a scoping review was conducted in line with PRISMA-ScR guidelines (Mattos et al., 2023), supported by bibliometric analysis using VOSviewer software (Bukar et al., 2023). This methodological integration ensures systematic, transparent, and predictive insights into the development of deep learning research in education.

Method

This research adopts the Scoping Review approach to systematically map the trends, gaps, and future directions of research related to deep learning in the context of education (Peters et al., 2021; Xue et al., 2024). The choice of this method is grounded in the broad, multidisciplinary, and dynamic nature of the topic, which is less suitable for quantitative synthesis through meta-analysis. Instead, a Scoping Review provides a more flexible framework to address exploratory questions and generate comprehensive mapping of literature in an evolving domain such as Artificial Intelligence in Education. The review process followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines (Mattos et al., 2023) ensuring a systematic and transparent procedure in identifying, selecting, and presenting the data. The main database employed in this study was Scopus, selected for its multidisciplinary coverage, comprehensive metadata, and advanced search functions that support Boolean operators. The search formula applied was TITLE-ABS-KEY ("deep learning"). The temporal scope was set between January 1, 2000, and March 31, 2025. The year 2000 was determined as the starting point to capture the early stage of deep learning adoption in educational research, while March 31, 2025, was chosen as the cutoff to ensure the inclusion of the most recent publications available at the time of data collection.

To ensure consistency, the inclusion criteria were limited to peer-reviewed scientific journal articles and review articles indexed in Scopus, written in English, and belonging to the subject areas of Education and Social Sciences. Articles were also included if they were available either through open access or via institutional subscription. Exclusion criteria were applied to eliminate non-peer-reviewed publications such as conference proceedings, book chapters, notes, or editorials, as well as articles that focused solely on technical aspects of computer science without an explicit connection to education.

Inclusion and Exclusion Criteria

Documents were selected using the following inclusion criteria: contain a combination of keywords "deep learning" and "education", are Scopus indexed scientific articles, published in the range of 2000-2025, and have complete metadata. The exclusion criteria include: editorials, opinions, book reviews, conference proceedings without peer review, and articles that discuss deep learning outside the educational context.

PRISMA Selection Process and Flow

The selection procedure is carried out in four stages according to the PRISMA-ScR protocol, namely: initial document identification from search results, Filtering based on title and abstract, topic eligibility and suitability, and final inclusion, after duplication removal. The PRISMA flowchart was used to document the number of documents at each stage along with the reasons for exclusion.

The article identification process was carried out using the Scopus database with the keyword "Deep Learning" for the period 2000 to 2025. The initial search yielded 11,211 documents. During the identification stage, 2,913 documents were eliminated because they did not fall within the field of Social Sciences. Next, filtering was carried out by focusing on publications in the form of journal articles. This process yielded 2,264 documents, but 968 records were then eliminated because they were not in the form of articles (e.g., notes or non-article documents). This left 1,296 journal articles for further analysis. The next stage was a feasibility test by reading the entire article. Of the 1,296 articles, some were eliminated because they were deemed irrelevant or outside the context of education. After the final selection, the number of articles that met the criteria and were included in the analysis was 491 articles.
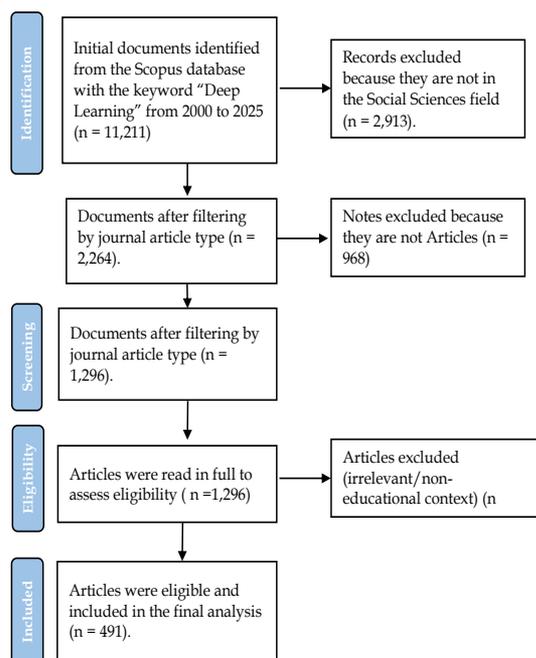

Figure 1. Prism flow diagram

Data Extraction and Analysis

Selected documents were extracted into a charting table that included: author name, year of publication, institutional affiliation, educational domain, methodological approach, and main keywords. Next, bibliometric analysis was conducted using VOSviewer

software with three main analysis approaches: Co-occurrence analysis to evaluate the connectedness of keywords, Network visualization to identify thematic clusters, and Overlay visualization to trace the temporal evolution of keywords in the range 2000-2025. The visualization results were used to answer the three main questions of this study: identification of dominant trends, mapping of research gaps, and projection of future research directions. Validation of interpretations was done through a search of key literature that acted as nodes in each cluster's keyword network.

Result and Discussion

Based on the analysis of 462 documents from the Scopus database, the research trend of "Deep Learning in Education" showed a sharp increase in the last decade. In the period 2000-2015, the number of documents was very low, averaging 0-5 documents per year, with the citation rate also minimal. The increase began in 2016 and has increased significantly since 2018. 2019 and 2020 recorded around 30-35 documents per year. This trend continues to rise, reaching 50-80 documents in 2021-2022, accompanied by a surge in citations of more than 2,000 citations per year. The year 2023 saw a peak in the number of publications with more than 110 documents, while 2024 saw a peak of more than 3,500 citations. Despite a dip in 2025, the 2018-2024 trend marks the explosive momentum of deep learning research development in education.
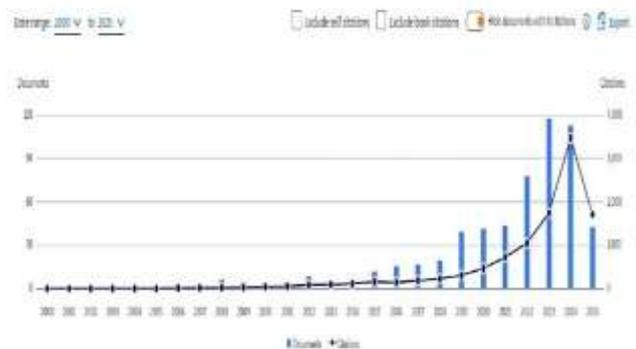

Figure 2. publication graph

The VOSviewer density visualization shows high-frequency keywords such as system, group, questionnaire, score, deep learning approach, and artificial intelligence, indicating the concentration of research on adaptive learning systems and academic evaluation. Supporting words such as test, factor, and curriculum also appear frequently. Meanwhile, terms such as covid, student performance, and connection showed moderate to low frequency. This reflects the main focus of research on AI-based interventions,

measurement of learning outcomes, and implementation of technology-based education systems.
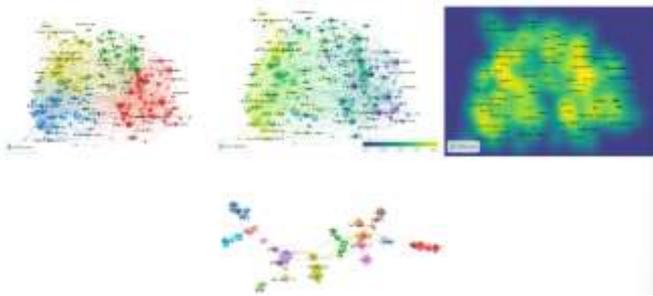

Figure 3. VOSviewer analysis results

The network visualization shows four dominant clusters. The red cluster highlights evaluative and experimental themes through words such as test, score, factor, and questionnaire, indicating a focus on experimental design and measuring the effectiveness of learning models. The green cluster presents pedagogical aspects and student perceptions, indicated by words such as curriculum, interview, perception, and reflection, which signify a qualitative approach. The yellow cluster contains systemic and bibliometric themes such as system, field, artificial intelligence, and trend, illustrating scientific mapping and policy direction. The blue cluster emphasizes the technical side through the terms accuracy, deep learning model, experiment, and technique, indicating exploration of algorithm efficiency and predictive model development.

The overlay visualization presents the temporal distribution. Keywords that appear early (dark blue) include experiment, test, and accuracy, reflecting the early phase of research focused on technical effectiveness. Over time, new bright yellow keywords such as chatGPT, natural language processing, further research, web, and trend emerged, indicating a shift in focus towards more generative and reflective systems. These developments confirm the dynamic evolution of deep learning research from a technical approach to systemic and strategic reflection in education.

Based on the keyword mapping, four main clusters were identified. Cluster 1 (65 items) focuses on experiment-based assessment and measurement of learning outcomes, including keywords such as academic achievement, test, and control group. Cluster 2 (55 items) emphasized pedagogical and social dimensions through terms such as critical thinking, collaborative learning, and interview. Cluster 3 (54 items) covers technical and algorithmic aspects, including algorithm, neural network, and prediction. While Cluster 4 (43 items) reflects futuristic and strategic approaches with words such as artificial intelligence, educational technology, chatGPT, and systematic review.

Table 1. Research theme clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
academic achievement	absence	accuracy	analytic
academic performance	achievement	action	answer
academic year	active learning	advantage	application
adoption	barrier	algorithm	art
age	case	artificial neural network	artificial intelligence
association	collaboration	behavior	author
attitude	collaborative learning	capability	bibliometric analysis
cohort	communication	capacity	big data
comparison	competence	category	chatgpt
contrast	connection	characteristic	china
control	covid	child	computer
control group	creativity	complexity	country
correlation	critical thinking	contribution	decision making
current study	culture	convolutional neural network	depth
deep approach	curriculum	creation	diversity
deep learning approach	degree	dataset	educational technology
deep learning strategy	delivery	day	engineering
difference	emotion	decision	english
dimension	face	deep	example
evidence	focus group	deep learning algorithm	extent
experimental group	format	deep learning model	field
factor	higher education institution	educational context	focus
factor study process question	higher education student	educational institution	further research
female	inquiry	efficiency	future
gender	interview	emphasis	game

Cluster 1	Cluster 2	Cluster 3	Cluster 4
grade	learning experience	experiment	gap
group	lesson	feature	health
improvement	majority	future research	keyword
individual	module	image	language
instrument	observation	industry	machine learning
item	online	large number	natural language processing
learning approach	online learning	life	possibility
lecture	pandemic	light	potential
male	participation	limitation	recent year
male student	patient	machine	reference
meaningful learning	pedagogy	mechanism	researcher
medical education	peer	network	review
medical school	perception	neural network	system
medical student	place	online education	systematic review
medicine	principle	pattern	text
participant	programme	precision	topic
pre	qualitative data	prediction	trend
preference	qualitative study	random forest	web
present study	reflection	range	
previous study	satisfaction	recall	
questionnaire	Self-efficacy	recommendation	
reliability	semi	significance	
respondent	sense	society	
sample	session	state	
scale	student engagement	student performance	
score	teaching practice	success	
self	team	technique	
significant difference	theme	user	
statistical analysis	transition	world	
style	video		
surface			
surface approach			
surface learning			
test			
total			
undergraduate student			
university student			
validity			
variable			
woman			

Overall, the data shows that deep learning research in education is rapidly evolving with thematic patterns involving the domains of academic experimentation, experiential learning, technological innovation and policy reflection. The visual, chronological and structural developments presented reinforce the urgency to understand trends, identify gaps and design future research directions in a more contextualized and collaborative manner

Discussion

This research revealed significant growth patterns and thematic characteristics in the literature on "Deep Learning in Education" over the period 2000 to 2025. The findings show strong dynamics in terms of trends, gaps and future directions of research. This section organizes the discussion around three main foci: research trends, thematic and methodological gaps, and strategic directions for future research development.

Research Trends

Publication and citation trends in the field of Deep Learning in Education have grown significantly since the mid-2010s. In the period from 2000 to 2015, the volume of publications was still very limited, with less than five documents per year and minimal citations, indicating low scholarly attention to this topic. However, since 2016, there has been a sharp acceleration in academic productivity. This peaked in 2023 with more than 110 publications and the highest citations in 2024

with more than 3,500 citations. This phenomenon is in line with the global digital transformation of the education sector as well as the penetration of generative artificial intelligence such as ChatGPT into classrooms, which is driving deeper academic exploration of AI-based learning (Barelli et al., 2025; Filius et al., 2018; Lee & Kim, 2023; Li & Song, 2025; Ong & Young, 2023; Pinheiro & Alves, 2024; Poort et al., 2023; Timperley & Schick, 2025; Verma et al., 2023; Winje & Løndal, 2023).

Visualization of density using VOSviewer shows a very high concentration of research themes on technical and evaluative aspects. Keywords such as system, score, questionnaire, and deep learning approach indicate that most studies are focused on developing intelligent learning systems, AIbased evaluation instruments, and strategies for improving academic outcomes. In this domain, many studies are developed through quantitative approaches and controlled experiments (Heijne-Penninga et al., 2008; Persky & Pollack, 2008; Verma et al., 2023; Wulff et al., 2023; Zhang, 2025). The red cluster in the network visualization reinforces the dominance of quantitative, experiment-based research, while the green cluster presents a pedagogical approach that emphasizes student perception, reflection, and learning experiences.

In addition, the yellow and blue clusters point to two other important trends. The yellow cluster signifies a strengthening of technology-based scientific and educational policy mapping, characterized by the occurrence of words such as system, field, and trend. Meanwhile, the blue cluster shows a shift to the technical dimension through the exploration of accuracy, deep learning models, and techniques in the development of predictive algorithms for education (Burkšaitienė & Šliogerienė, 2021; Kochmar et al., 2022; Rodrigo & Platon, 2022; Webb et al., 2021). This change in focus is also reflected in the overlay visualization, where classic terms such as experiment and test are being replaced by new keywords such as chatGPT, natural language processing, and further research. This indicates a conceptual transition from a narrow focus on technology validation towards systemic exploration, ethical reflection, and the design of more complex and adaptive AI-based learning (Chaudhry et al., 2023; Kahn & Winters, 2021; Meddeb et al., 2021; Sharadgah & Sa'di, 2022; Suherman et al., 2023).

Research Gaps

Despite the exponential growth of the literature on deep learning in education, this research reveals a number of critical gaps that have not been systematically addressed. Topically, the majority ofstudies are still concentrated in the context of higher education and STEM fields. Most of the literature places deep learning as a tool in big data processing, pattern recognition, or recommendation systems in university-level online learning (McLean & Bottrell, 2022; Mulualem et al., 2022; Ong & Young, 2023). Meanwhile, the use of deep learning in primary education and the humanities is rarely studied in depth. Studies from Southeast Asia, Africa and Latin America, for example, are limited in number and depth, creating geographical and epistemological gaps in the global narrative (Carrim, 2022; Ganda et al., 2014; Ross et al., 2022).

The second gap is seen in the absence of affective, ethical and social dimensions in research design. The dominant focus on cognitive aspects and academic performance has led to the neglect of the role of emotions, identity, and (Gotlieb et al., 2021; Howell, 2021; Kovač et al., 2023; Mooney Simmie, 2023; Suen & Hung, 2025; Vala & Jaliya, 2022; Villarroel & González, 2023; Zong et al., 2022), human values in AI-based education. The lack of attention to ethics, inclusion and well-being in deep learning-based education systems can create structural biases, especially when applied to vulnerable populations such as children or students with special needs. Not many studies have included ethical frameworks or inclusive design principles in the development of AI models for learning.

The third gap lies in the disconnect between conceptual research and real implementation contexts. Most research relies on simulation or task-based testing in digital laboratory environments, rather than on longitudinal testing or real classroom practice (Bulut et al., 2024; Gredes et al., 2022; Jamil & Bhuiyan, 2021; Pouragha et al., 2019; Ramasamy & Ramamoorthy, 2022). Technology impact assessments still focus on instruments such as questionnaires and pre-posttests, but not many have examined learning trajectory, engagement, or teacher-student interaction holistically. This has led to many AI applications in education failing to be sustainably adopted because they do not consider local context, user readiness, and complex classroom dynamics.

Future Directions for Research

The overlay findings from the bibliometric analysis indicate a significant shift in the direction of deep learning in education research, from an experimental focus towards reflective, transformative and systemic approaches. Keywords such as chatGPT, natural language processing, trends, and systematic review indicate that future approaches will be more about utilizing generative technologies and responding to contemporary educational challenges (Agbo et al., 2021; Aljarrah et al., 2021; Kochmar et al., 2022; Rodrigo & Platon, 2022). One important direction is the integration of deep learning with transdisciplinary approaches,

including human-computer interaction (HCI), digital ethics, and adaptive pedagogy. Many studies highlight the importance of designing AI systems that are not only adaptive, but also ethical and inclusive, and also that deep learning approaches in education need to pay attention to algorithmic fairness, data bias, and the socio-cultural context of learners (Gouraguine et al., 2023; Hoh, 2025; Nakhooda & Paxton, 2021; Ryan & Aasetre, 2021; Tarrant et al., 2021). Collaboration between technology developers, educators and policy makers is crucial. Future research needs to involve stakeholders in the design and evaluation process of AI-based systems to ensure social acceptability and sustainability of implementation (Abdullah & Almaqtari, 2024; Saqr et al., 2023; Trechsel et al., 2022). Successful deep learning systems in the future will not only be technically accurate, but pedagogically relevant and sensitive to contextual needs. In the context of higher education, review-driven approaches and evidence-based policies will play a strategic role. Future research should address social and epistemological sustainability aspects in the design of educational AI systems. The future of deep learning research in education demands a more integrative, collaborative and reflective perspective. The transition from algorithmic efficiency to equity and transformative impact will determine the value of AI-based educational innovations.

Conclusion

This study systematically mapped the trends, gaps and future directions of deep learning research in education over the period 2000-2025 using a PRISMA-ScR-based scoping review approach. Analysis of 491 documents from the Scopus database shows that publications on this theme have experienced a significant surge since 2018, with peak productivity occurring in 2023 and peak citations in 2024. This surge reflects the urgency of adopting deep learning as part of the digital transformation of global education, especially in the development of adaptive learning systems, predictive analytics and evaluation automation. The bibliometric analysis identified four main thematic clusters: experiment-based academic assessment, learner perception and experience, algorithmic approaches, and systemic reflection on educational technology. The findings show that although technical exploration is dominant, the ethical, social, affective dimensions, as well as the local context are still minimally touched upon. In addition, there is significant geographical disparity, with minimal contributions from developing countries, and limited hands-on testing in real classrooms. Based on these findings, it is recommended that future research integrate a

transdisciplinary approach that incorporates aspects of pedagogics, digital ethics, and human-centered design. Future research needs to pay attention to the balance between algorithmic efficiency and social impact of education, especially in ensuring inclusion, equity of access, and sustainability of AI technologies. It is also recommended to expand the study to basic education, non-STEM, and Global South contexts that have been underrepresented in the literature map. The results of this study are expected to be an important reference for policy makers, researchers, and educational practitioners in designing an adaptive and equitable research, technology implementation, and policy framework in the era of AI-based learning.

Author Contributions
Conceptualization, A.J; methodology, A.J.; software, R.F.; validation, A.J., D.S. and I.M.; formal analysis, R.F.; investigation, A.J.; resources, D.S.; data curation, I.M.; writing—original draft preparation, A.J.; writing—review and editing, D.S.; visualization, I.M.; supervision, A.J.; project administration, R.F.

Conflicts of Interest
The authors declare no conflict of interest.

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