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Trends of Deep Learning Approaches in Elementary School: VosViewer-Assisted Bibliometric Analysis

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ABSTRACT

Objective: This study aims to analyze the trends, developments, and characteristics of global scientific publications regarding the deep learning approach in elementary schools over an eleven-year period (2015–2025) in order to overcome the limitations of systematic scientific mapping using computational bibliometric approaches in this field. **Methods:** This study used a quantitative bibliometric design, collecting metadata from 985 deep learning articles in elementary schools indexed through Harzing's Publish or Perish application. Statistical data processing was carried out using Microsoft Excel, followed by computational mapping and analysis of network visualization, density, and overlays using the VOSviewer application to test the relationship between keyword co-occurrence. **Findings:** The analysis revealed that there are 985 publications with fluctuating trends that tend to increase, peaking at 149 articles in 2025 with an average annual growth of 89.5 publications. The VOSviewer mapping identifies 5 interconnected keyword clusters where the terms "deep learning", "elementary schools", "machine learning", and "implementation" form the core with the highest density. Meanwhile, topics that emerged as cutting-edge trends include Project-Based Learning (PBL) and learning outcomes (outcomes). **Research Implications:** These findings provide a comprehensive reference for researchers to determine future research directions, in particular highlighting pedagogical applied issues driven by digital technology change, and offer a foundation for stakeholders to integrate Artificial Intelligence technology in the active learning ecosystem in primary schools. **Originality:** This research contributes to presenting a unique eleven-year computational mapping of deep learning publications in elementary schools, as well as successfully uncovering research gaps that are still rarely touched, such as aspects of cognitive transfer ability and students' creativity in this discipline.

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INTRODUCTION

Deep learning as a sub-field of Artificial Intelligence (AI) has brought a new paradigm in various sectors, including the world of formal education. In the context of primary education, the deep learning approach refers to the use of cutting-edge artificial neural network-based technology to create a learning system that is adaptive, personalized, and able to recognize children's learning patterns in depth (LeCun et al., 2015). In today's digital era, the urgency of deep learning integration in elementary schools is based on the need to facilitate the alpha generation's visual, interactive, and technology-based learning style (Zhai, Chu, Chai, Jong, Istenic, Spector, et al., 2021). The implementation of this technology is projected to be able to support teachers in conducting automatic assessments, detecting reading or arithmetic difficulties from an early age, and presenting curriculum content that is tailored to the learning speed of each student (Chen et al., 2020). Therefore, understanding how deep learning is developed and implemented at the elementary school level is a crucial prerequisite for overseeing the evolution of pedagogy relevant to the demands of the 21st century.

Many previous studies have explored the use of artificial intelligence-based technologies and deep learning at the basic education level from various perspectives. These studies include the integration of deep learning in ai-based learning to improve primary school teachers' digital literacy (Mbuik et al., 2026), Transforming Elementary Mathematics Learning Through Deep Learning: Strategies to Increase Motivation and Performance (Novita Barokah

& Umi Mahmudah, 2025), The Effectiveness of Improving Artificial Intelligence-Based Learning (Muin & Kusmaladewi, 2025). Most of the literature focuses on small-scale experimental trials or specific software module development in one or two partner schools.

Based on some previous literature, although empirical studies on the practical application of this technology in early childhood and elementary school have been conducted, there is still a scarcity of research that maps global publication trends regarding the deep learning approach in elementary schools comprehensively using a bibliometric visual approach. Recently, the use of bibliometric analysis has often been used by many previous studies in determining research trends, systematically tracking research trajectories, uncovering structural gaps, and setting future research agendas (Nandiyanto & Al Husaeni, 2021). Therefore, this study aims to analyze global publication trends regarding the deep learning approach in elementary schools using bibliometric analysis methods assisted by mapping analysis. Bibliometric analysis is one of the widely used approaches to map the development of scientific knowledge, identify dominant themes, and examine the relationships between concepts in a field of research (Nandiyanto & Al Husaeni, 2021). This method allows researchers to analyze the patterns of publication, collaboration, and dynamics of research topics based on widely indexed scientific data. The use of VOSviewer software in bibliometric analysis has been shown to be effective in visualizing keyword networks, temporal trends, and research topic densities across multiple disciplines (Ding & Yang, 2022).

This study also analyzes research developments, citation dynamics, and influential contributors in this domain. Ultimately, we use mapping visualization to define discussion keywords to identify research clusters, track historical thematic shifts, and pinpoint under-researched areas to guide future primary education researchers. Previous research that discussed research trends using Global trends and future prospects of e-waste research: a bibliometric analysis (Gao et al., 2019), serta bidang bisnis melalui Trends and patterns in digital marketing research: bibliometric analysis (Ghorbani et al., 2022), Trends in Influencer Marketing: A Review and Bibliometric Analysis (Tanwar et al., 2022), Emerging trends in the literature of value co-creation: a bibliometric analysis (Saha et al., 2020), dan AI applications in business: Trends and insights using bibliometric analysis (Dissanayake et al., 2024). The use of this method is also reinforced by methodological suggestions in Bibliometric analysis: A few suggestions (Hassan & Duarte, 2024).

Several other previous studies have also shown the flexibility of this method in tracking technological disruptions and global trends, such as Multirisk: What trends in recent works? A bibliometric analysis (Curt, 2021), Emerging trends in digital transformation: a bibliometric analysis (Chawla & Goyal, 2022), Highway Planning Trends: A Bibliometric Analysis (Castañeda et al., 2022), Global Trends on Food Security Research: A Bibliometric Analysis (Xie et al., 2021), Exploring two decades of research on classroom dialogue by using bibliometric analysis (Song et al., 2019), A bibliometric analysis of global trends of research productivity in tropical medicine (Falagas et al., 2006), Trends in research on climate change and organizations: a bibliometric analysis (1999–2021) (Díaz Tautiva et al., 2024), A bibliometric analysis of Quality 4.0: current status, trends and future research directions (Kushwaha & Talib, 2025), Bibliometric analysis on global Parkinson's disease research trends during 1991–2006 (T. Li et al., 2008), Future trends and guidance for the triple bottom line and sustainability: a data driven bibliometric analysis (Tseng et al., 2020), Global trends and prospects in microplastics research: A bibliometric analysis (Zhang et al., 2020), Which Industrial Sectors Are Affected by Artificial Intelligence? A Bibliometric Analysis of Trends and Perspectives (Espina-Romero et al., 2023), Global trends in the scientific research of the health economics: a bibliometric analysis from 1975 to 2022 (Barbu, 2023), Research trend of metal–organic frameworks: a bibliometric analysis (Wang & Ho, 2016), Research hotspots, trends and opportunities on the metaverse in health education: a bibliometric analysis (Agac et al., 2025).

METHOD

This study uses a quantitative research design with a computational bibliometric analysis approach to map and evaluate the structural dynamics of scientific publications in the field of applying deep learning approaches at the elementary school (SD) level. The data source for this study consists of academic literature indexed in the Google Scholar database, which was chosen for its broad scope and high accessibility to publications on competencies and technological innovations in primary education. The data population includes all scientific articles that contain the keywords "Deep Learning in Elementary School" or "Deep Learning in Elementary School" in their metadata. The purposive sampling method was applied to determine the sample of research data based on strict inclusion criteria: the article must be directly relevant to the core topic, published within a ten-year time span from 2015 to 2025, and complete metadata retrieval must be completed by December 2024. Through this screening process, a total sample of relevant articles is extracted for further evaluation.

The data collection instruments and procedures are carried out systematically using Harzing's Publish or Perish software, which serves as the primary tool for retrieving, codifying, and filtering article metadata from databases. The data capture process captures crucial publication attributes, including the author's name, article title, year of publication, journal name, publisher, number of citations, and the URL of each article. Once metadata extraction is complete, the collected data is exported into two different file formats: Research Information System (.ris) for visual mapping and Comma-Separated Values (.csv) for statistical profile analysis.

The data analysis technique involves two integrated phases: descriptive statistical profiling and computational bibliometric mapping. In the first phase, Microsoft Excel is used to process .csv files to calculate total publications, annual distributions, and descriptive citation metrics including h-index and g-index. In the second phase, the .ris file is imported into the VOSviewer application to perform network analysis based on the co-citation and co-occurrence of the term or keyword. VOSviewer generates three variations of bibliometric visualizations to uncover research gaps: network visualization to analyze the linkages between topics, density visualization to observe the frequency of specific research themes, and overlay visualization to evaluate the chronological novelty of keywords over the ten-year period.

RESULTS

Data exploration through the Harzing's Publish or Perish application from the Google Scholar database succeeded in capturing as many as 985 articles that met the inclusion criteria related to the trend of deep learning approaches in elementary schools (SD). The extracted dataset managed to collect a total of 354905 citations over the ten-year citation period (2015-2025). This massive accumulation of citations indicates that the discourse on the integration of artificial intelligence and deep learning at the primary education level has a very strong appeal and is an important reference for the global academic community. The full citation metrics resulting from the extraction of such software are detailed in Figure 1.

Citation metrics	Help
Publication years:	2015-2025
Citation years:	11 (2015-2026)
Papers:	985
Citations:	354905
Cites/year:	32264.09
Cites/paper:	360.31
Cites/author:	196870.91
Papers/author:	470.01
Authors/paper:	2.83
h-index:	276
g-index:	583
hI,norm:	183
hI,annual:	16.64
hA-index:	109
Papers with ACC >= 1,2,5,10,20:	

Figure 1. Citation Metrics of Deep Learning Approaches in Elementary School Publications from Google Scholar Database via Publish or Perish

The statistical data in Figure 1 reveals that scientific publications in this domain get an average of 32264.09 citations per year and 360.31 per article, in addition to an average of 196870.91 citations per author. This dataset shows a very high level of academic impact, which is indicated by an h-index value of 276 and a g-index of 583. The density of collaboration between researchers showed an average of 470.01 articles per author and 2.83 authors per article. These figures prove that the discourse on deep learning integration in elementary schools is no longer just a fringe topic, but has become a mainstream of global research that is carried out collaboratively by various experts across institutions. To provide a preliminary overview of the most influential literature in this data corpus, the structural profiles and citation metrics of the 21 highest-cited articles are compiled in the Table.

Table 1. Deep Learning at Elemntary School Publication Data

Nu.	Author	Title	Year	Citations	Reference
1	M Fullan	The new meaning of educational change	2016	41632	(Fullan, 2016)
2	J Bergmann, J Bergmann, A Sams	Flip your classroom, revised edition: Reach every student in every class every day	2023	12999	(Bergmann et al., 2023)
3	F Chollet, F Chollet	Deep learning with Python	2021	9721	(Chollet & Chollet, 2021)
4	MA Nielsen	Neural networks and deep learning	2015	6720	(Nielsen, 2015)
5	L Darling-Hammond, L Flook…	Implications for educational practice of the science of learning and development	2020	6617	(Darling-Hammond et al., 2020)
6	CC Aggarwal	Neural networks and deep learning	2018	5143	(Aggarwal, 2018)
7	L Floridi, M Chiriatti	GPT-3: Its nature, scope, limits, and consequences	2020	4507	(Floridi & Chiriatti, 2020)
8	TE Deal, KD Peterson	Shaping school culture	2016	4215	(Deal & Peterson, 2016)
9	A Collins, D Joseph, K Bielaczyc	Design research: Theoretical and methodological issues	2016	4069	(Collins et al., 2016)
10	A Collins, R Halverson	Rethinking education in the age of technology: The digital revolution and schooling in America	2018	3417	(Collins & Halverson, 2018)
11	WM Lim	What is qualitative research? An overview and guidelines	2025	2854	(Lim, 2025)
12	J Gee	The new work order	2018	2798	(Gee, 2018)
13	A Tlili, B Shehata, MA Adarkwah, A Bozkurt…	What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education	2023	2773	(Tlili et al., 2023)
14	S Li, W Deng	Deep facial expression recognition: A survey	2020	2731	(S. Li & Deng, 2020)
15	P Lu, S Mishra, T Xia, L Qiu…	Learn to explain: Multimodal reasoning via thought chains for science question answering	2022	2640	(Lu et al., 2022)
16	M Fullan	The principal 2.0: Three keys to maximizing impact	2023	2519	(Fullan, 2023)
17	VJ Shute, C Sun, J Asbell-Clarke	Demystifying computational thinking	2017	2298	(Shute et al., 2017)
18	X Zhai, X Chu, CS Chai, MSY Jong, A Istenic…	A Review of Artificial Intelligence (AI) in Education from 2010 to 2020	2021	2275	(Zhai, Chu, Chai, Jong, Istenic, & ..., 2021)
19	RP Weissberg, JA Durlak, CE Domitrovich, TP Gullotta	Social and emotional learning: Past, present, and future.	2015	2243	(Weissberg et al., 2015)
20	M Fullan	The new meaning of educational change	2016	41632	(Fullan, 2016)

Table 2 presents the annual growth trend of the 985 articles successfully mapped during the period 2015 to 2025. The chronological data highlight the baseline as well as the specific growth rate of scientific publications related to the deep learning approach in elementary schools in the last eleven years.

Table 2. Annual Publication Distribution from 2015 to 2025

Year	Number of Publication
2015	77
2016	79
2017	84
2018	89
2019	75
2020	92
2021	95
2022	66
2023	84
2024	95
2025	149
Total	985
Average	**89,5**

Based on Table 2, the chronological distribution of the 985 articles mapped from 2015 to 2025 shows fluctuating dynamics that tend to increase significantly by the end of the decade. At the beginning of the observation period (2015–2018), research on deep learning at the elementary school level showed steady growth with an average of about 82 publications per year. Although there was a decline in 2019 (75 articles) and the sharpest decline in 2022 (66 articles), which was most likely influenced by the shift in global research focus post-pandemic, this trend has managed to rise progressively again.The most massive surge in publications will occur in 2025 with the highest number of 149 articles. This figure jumped sharply from the annual average of 89.5 publications. The phenomenon of a surge in 2025 indicates that the integration of deep learning approaches in primary education is no longer just a minor technological experiment, but has become a mainstream research that is in great demand by global academics as the artificial intelligence ecosystem in the classroom matures.

To test the internal semantic structure and thematic relevance of the collected datasets, VOSviewer's computational mapping analysis successfully identified 75 keywords that had strong relationships. The keywords are automatically grouped into 5 different thematic clusters. Network visualization that describes the distance and co-occurrence relationship between the core nodes is presented in Figure 2.

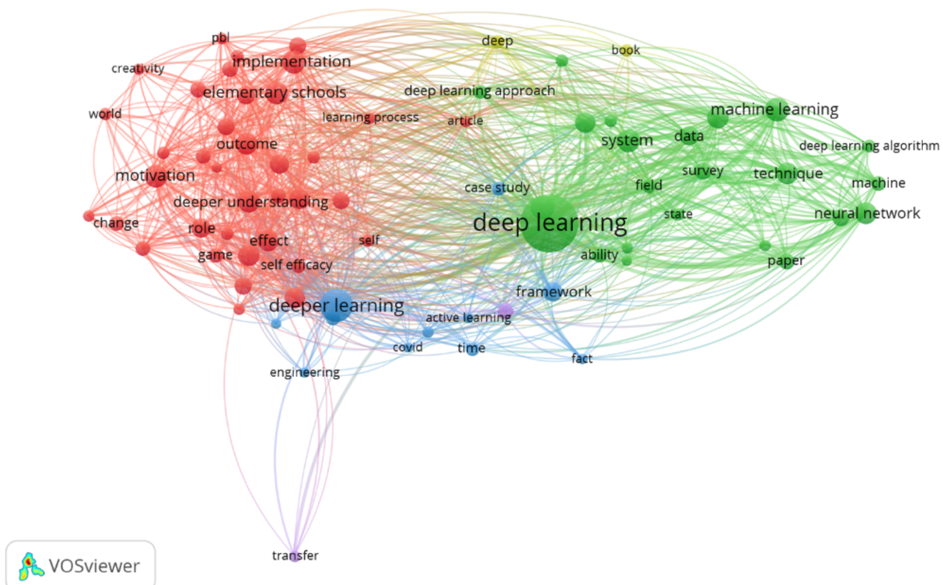

Figure 2. Network Visualization of Deep Learning in Elementary Education Keywords.

Based on the results of computational mapping using VOSviewer presented in Figure 2, the network visualization shows strong interconnections between keywords divided into several main color clusters. The term "deep learning" occupies the central position with the most massive node diameter within the green cluster. This indicates that the topic of artificial intelligence (Artificial Intelligence) based on deep learning is the main focus that is the most intensively researched. These nodes are strongly connected to technical operational terms such as "machine learning", "neural network", "system", and "technique".

The interesting thing about Figure 2 is the formation of red clusters that specifically represent the pedagogical realm at the basic education level. The term "elementary schools" is one of the dominant nodes in this red cluster and has very close linkages with "implementation", "outcome", and "motivation". This relationship proves that the trend of deep learning research in elementary schools does not stop at the development of algorithms alone, but has shifted towards how the practical implementation of the technology can affect learning outcomes and learning motivation of early childhood students.In addition, the appearance of specific keywords such as "pbl" (Project-Based Learning) in the red cluster, as well as its connection to the large "deeper learning" node in the blue cluster, gives an idea of the convergence of methods. Future research trends tend to integrate deep learning technology approaches with project-based active learning models to stimulate students' deeper understanding and knowledge transfer capabilities.

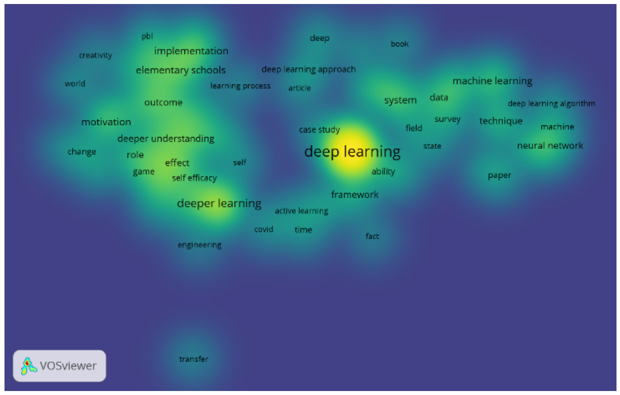

Figure 3. Density Visualization of Deep Learning Research in Elementary Schools

Density visualization recorded in Figure 3, provides an explicit picture of the concentration and saturation of research in the dataset. The color gradation that transitions from light blue to bright yellow indicates the frequency and density of the term appearing simultaneously. The keyword "deep learning" glows with the highest light intensity at the absolute center, confirming its status as the most saturated and most researched core domain. Around the central node, medium-density zones (green areas) are seen around "deeper learning", "elementary schools", and "machine learning", reflecting established research sub-pathways that bridge AI technology with basic education pedagogy. In contrast, peripheral regions (edges) marked by a faint blue glow, such as "transfer", "creativity", "engineering", and "covid", show a still low density of publications. These low-density nodes present a valuable research gap. This signals a crucial opportunity for future researchers to delve deeper into how specific applications of deep learning can drive students' creativity or cognitive transfer abilities within STEM/engineering frameworks in elementary schools.

In addition to mapping the density and relationships between keywords, it's important to understand how those topics have evolved over time. Therefore, the analysis was continued by using Overlay Visualization on VOSviewer to track the chronological trends of deep learning research in elementary schools during the period 2015 to 2025. This visualization presents a temporal roadmap that illustrates how the focus of academia shifts from theoretical foundations to practical renewal, as shown in Figure 4.

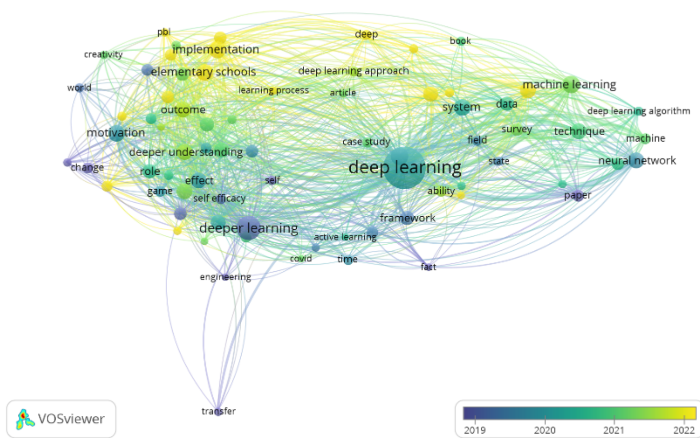

Figure 4. Overlay Visualization of Keyword Trends

A chronological analysis of thematic evolution is presented through Overlay Visualization in Figure 4 This overlay map uses color gradations from dark purple (2019) to bright yellow (2022) to map the novelty of the term as well as the shift in the focus of deep learning research at the elementary education level in recent years. Based on Figure 4, the terms in the lower and right peripheral positions such as "transfer", "paper", "change", and "framework" are dominated by dark purple. This confirms that around 2019, the initial focus of the research was still on laying down the theoretical framework and structural aspects of the technology. Entering the transition phase (2020–2021) which is characterized by teal green to leaf green, the researcher's attention shifted massively towards the technical support of computing and learning adaptation models, which is reflected by the nodes of "deep learning", "machine learning", "deeper".

The most crucial paradigm surge was seen at its peak in 2022, where the keyword cluster on the top left side glowed with a very dominant bright yellow. Terms such as "elementary schools", "implementation", "pbl" (Project-Based Learning), and "outcome" are the main drivers of the latest research trends. This chronological dynamic proves a very directional shift in focus: from research that was initially technical-algorithmic, isolated to practical action research in elementary schools. Researchers are currently much more interested in testing the real implementation of deep learning through active learning models (such as PBL) to measure the real outcomes of elementary school students.

DISCUSSION

The empirical results resulting from bibliometric computational mapping provide several critical interpretations of the structural trajectory of the deep learning literature in elementary schools. The longitudinal data collected in Table 2 reveal that this field is experiencing dynamic structural fluctuations. A stable baseline between 2015 and 2018 indicates a period of fundamental consolidation, which further triggers aggressive expansion to peaking in 2025 with 149 articles. This surge reflects a shift in global education that recognizes Artificial Intelligence competencies as a crucial 21st-century skill at the primary education level. This is in line with the theoretical argument that technological adaptation from an early age is important to shape the ability of adaptive human resources in the future. On the other hand, the sharp decline that had occurred in 2022 (66 articles) signaled a temporary shift in research momentum due to post-pandemic adjustments, before finally surging back massively.

Integrating these findings into a broader scientific structure, the data profile shows that the scientific impact of deep learning in elementary schools is not stand-alone, but rather highly cross-disciplinary. The focus of this research is closely intersected with the STEM framework, the use of interactive media (such as books and games), and educational psychology related to children's learning motivation. The presence of this high-performance publication proves that deep learning technology has been deeply embedded in modern educational innovation and the structural sociology of elementary schools. The primary novelty revealed in this study lies in the visualized structural friction between network density and chronological overlay. While Figure 2 and Figure 3 confirm that traditional behavioral outcomes and general capability analysis form the core of a highly researched discipline, the dimming peripheral regions reveal crucial research gaps. The low density around the nodes of "transfer" and "creativity" exposes the missing link in the current educational literature. This structural gap indicates that although scholars are studying the macroscopic implementation of deep learning on outcomes, the microscopic mechanisms of how these technologies train elementary school children's cognitive transfer skills and creativity in solving real problems are still very poorly researched.

Furthermore, the visualization of the overlay in Figure 4 shows a profound conceptual transformation in the structure of this discipline. The clear temporal shift from traditional classroom concepts and basic technical terms (purple/blue nodes circa 2019) to applied technology-based keywords such as "implementation" and "pbl" (Project-Based Learning) (bright yellow nodes of 2022) indicates that the boundaries of deep learning research are evolving rapidly. This evolutionary pattern implies that the use of AI in elementary education is no longer limited to testing static algorithms or computing systems; rather, it has shifted towards adaptive digital interaction combined with an active learning model to optimize students' learning processes. For practical and theoretical implications, these findings provide a strategic blueprint for policymakers and academic institutions. Rather than rehashing already saturated research on algorithm efficiency in general, curriculum design and future research should intentionally focus on these newly identified open spaces, specifically targeting the development of student creativity and the integration of deep learning applications into standardized project-based learning ecosystems in elementary schools.

CONCLUSION

This research has succeeded in achieving its goal of mapping the evolution and trends of global research regarding deep learning approaches in elementary schools during the period 2015 to 2025 using a computational bibliometric approach. Based on empirical data extracted from 985 articles, the field shows a dynamic scientific foundation with an average annual publication of 89.5 articles. The publication trend is reported to have developed progressively until it peaked in 2025 with 149 articles, after previously experiencing a low point in 2022 due to post-pandemic adjustments. Furthermore, computational mapping through VOSviewer managed to identify 13 different thematic clusters, in which the terms "deep learning" and "elementary schools" form the core of the most densely researched disciplines. The temporal overlay data confirms a decisive structural transformation, where the focus of academics has shifted significantly from the theoretical concepts of basic algorithms (in 2019) to the practical applied domain (in 2022) including real implementation through Project-Based Learning (PBL) and the measurement of student outcomes in the classroom.

Structural density analysis reveals critical research gaps supported by visual data, where peripheral regions such as the "transfer" and "creativity" nodes have the lowest research saturation levels in the entire dataset. Based on these specific findings, follow-up recommendations for future research should move away from macro analysis of the general capabilities of AI technologies, and instead focus on the pedagogical tactical execution of deep learning. Future researchers are encouraged to design empirical studies that investigate how micro-deep learning applications are able to stimulate students' cognitive transfer abilities in solving real problems, evaluate the role of this technology in sparking early childhood creativity, and expand the bibliometric spectrum by conducting comparative meta-data analyses using other reputable external databases to enrich the roadmap of artificial intelligence research at the education level basic.

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