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Global Trends of Deep Learning in Education Policy: A Bibliometric Analysis and Implications for Indonesia

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ABSTRACT

The transformation of education in Indonesia through policies such as Merdeka Belajar–Kampus Merdeka requires more adaptive, data-driven learning approaches capable of addressing the complexity of learners' needs in the digital era. In this context, deep learning has become increasingly important due to its ability to analyze educational data deeply and support more accurate and context-sensitive decision-making. Therefore, this study aims to analyze the development, distribution, and research trends of deep learning in education policy, as well as to identify existing research gaps. This study employs a bibliometric approach using data sourced from the Scopus database. The search process was conducted through titles, abstracts, and keywords, followed by a refinement process based on specific criteria, resulting in 493 documents for analysis. Data analysis was carried out using a quantitative descriptive approach, focusing on publication trends, country distribution, and subject areas. The results indicate that publications on deep learning in education have increased significantly in recent years and are dominated by technologically advanced countries such as China, the United States, and the United Kingdom. In terms of subject areas, research is largely dominated by social sciences, suggesting that studies tend to focus more on policy, implementation, and educational impacts rather than purely technical aspects. Additionally, several research gaps were identified, including conceptual ambiguity, limited evaluation frameworks, and a gap between policy and practice. This study implies that the development of deep learning in education should adopt a multidisciplinary and contextual approach, taking into account the readiness of educational systems, particularly in Indonesia. The integration of deep learning is expected to strengthen educational policy implementation and improve the quality of learning in a sustainable manner.

Keywords: deep learning, education policy, bibliometric analysis, Indonesian education

INTRODUCTION

Educational policies in Indonesia in recent years have demonstrated a progressive and adaptive direction in response to global changes, particularly in addressing digital transformation and the demands of 21st-century competencies. One of the most prominent initiatives is the Merdeka Belajar–Kampus Merdeka (MBKM) program, which aims to promote learning flexibility, enhance the relevance of education to workforce needs, and foster critical thinking, creativity, and independent learning. This policy reflects the government's commitment to developing a more responsive, contextual, and competency-oriented education system.

In practice, MBKM has created broad opportunities for educational institutions to innovate in designing learning models, including project-based learning, interdisciplinary collaboration, and experiential learning beyond traditional classroom settings . This approach supports a

paradigm shift from instruction-centered learning toward more exploratory and student-centered learning processes. Thus, MBKM serves not merely as an administrative policy but as a transformative framework for reshaping educational practices.

However, the implementation of MBKM requires continuous support, particularly in strengthening human resource capacity, infrastructure readiness, and the integration of technology in learning processes. In this context, there is an increasing need for approaches capable of managing complex educational data and supporting evidence-based decision-making. Therefore, the development of data-driven learning approaches becomes an essential component in reinforcing educational policies.

Deep learning emerges as a promising approach to support this transformation. Its capability to process complex data enables deeper analysis of various learning aspects, including student interaction patterns and assessment outcomes. In educational settings, deep learning can facilitate the development of adaptive, personalized, and responsive learning systems tailored to individual learner needs (Hakiki et al., 2026; Wang & Chen, 2025) .

As research interest in deep learning continues to grow, studies have demonstrated its application in personalized learning, predictive analytics, and automated assessment systems that improve the effectiveness of educational processes (Pandang, 2025; Putri, Zahro, Widodo, & Suprapto, 2025; Zhou, Zhang, & Ding, 2025) . This indicates that deep learning plays a strategic role in advancing data-driven educational systems and enhancing learning quality.

Furthermore, the integration of deep learning aligns with the principles of MBKM, which emphasize flexible and student-centered learning. By leveraging deep learning, educational processes can be designed to better accommodate individual learner characteristics, thereby improving engagement and learning outcomes. This approach also supports the development of critical thinking and problem-solving skills, which are central to current educational policies (Winje & Løndal, 2020; Z. Zhang, 2025) .

Nevertheless, optimizing the role of deep learning in supporting educational policies requires a deeper understanding of its implementation within local contexts. Challenges such as teacher readiness, infrastructure availability, and alignment with existing educational systems remain important considerations. Research highlights that teacher readiness is a key factor in successful implementation, emphasizing the need for continuous professional development (Pahrudin et al., 2025).

In addition, ensuring alignment between policy and practice is essential so that innovations introduced through MBKM can be effectively implemented with appropriate technological support. In this regard, deep learning should be viewed not merely as a technological tool but as a strategic approach to strengthening educational quality and policy effectiveness.

METHODS

This study uses a bibliometric approach with the aim of analyzing the development, distribution, and characteristics of research related to deep learning policy in education. The bibliometric approach was chosen because it is able to provide a quantitative and systematic overview of publication trends, state contributions, and distribution of fields of knowledge in a research topic. This study uses a descriptive-analytical approach, where data is not only presented in the form of numbers, but also interpreted critically to understand research patterns, tendencies, and gaps.

This approach allows researchers to not only describe the development of research, but also to identify future research directions and opportunities for study development, particularly in the context of deep learning technology-based education policy.

1. Data Sources and Search Strategies

Research data was obtained from the Scopus database, which is one of the largest and reputable scientific index databases globally. The search process was carried out using the keyword "deep learning policy in education" which was applied to the title, abstract, and keywords sections.

The initial search results yielded 1,084 documents, covering different types of publications with varying degrees of relevance. To ensure the quality and relevance of the data, a refinement process is carried out using the limit to feature in Scopus.

2. Inclusion and Exclusion Criteria

The screening process is carried out based on several criteria as follows:

a. Publication timeframe: 2021–2025, to get an overview of the latest developments.
b. Type of document: scientific articles (articles), to ensure academic quality.
c. Language: English, to ensure consistency of analysis.
d. Topic relevance: a document that is directly related to deep learning in the context of education policy.

After the screening process was carried out, the number of documents was reduced to 493 documents, which were then used as the main dataset in bibliometric analysis.

3. Data Analysis Techniques

Data analysis was carried out by utilizing the Analyze Search Results feature on Scopus. The analysis focused on several key indicators, namely:

a. Distribution of publications by year, to identify trends in research developments.
b. Distribution by country/territory, to see the geographical contribution in scientific production.
c. Distribution by subject area, to identify the multidisciplinary character of the research.
d. Further analysis was carried out using a subset of data as many as 319 documents in the analyze results feature, especially to examine the distribution of science fields more specifically.
e. The data obtained was then analyzed using a quantitative descriptive approach, by calculating frequency, percentage, and comparing between categories to find distribution patterns and research trends.

4. Analysis Procedure

The research procedure is carried out through several stages, namely:

a. Identify keywords and search data in the Scopus database.
b. The initial data collection was 1,084 documents.
c. Data filtering based on inclusion and exclusion criteria until 493 documents were obtained.
d. Bibliometric analysis uses the analyze results feature.
e. Interpretation of data based on the distribution of years, countries, and fields of science.
f. Synthesis of findings to produce conclusions and implications of the research.

RESULT AND DISCUSSION

1. Search and Literature Screening Results

Literature search was conducted through the Scopus database using the keyword *"deep learning policy in education"* which focused on titles, abstracts, and keywords. Initial search

results showed 1,084 documents, indicating that this topic has become a fairly wide concern in global scientific studies. This number reflects the high academic interest in the integration of deep learning technology in the context of education, especially in the policy dimension.

However, the initial number still includes various types of documents with varying levels of relevance. Therefore, a refinement process is carried out by setting certain criteria, namely the 2021–2025 publication year range, the type of document in the form of articles, and the use of English. After the selection process was carried out, the number of documents analyzed further became 493 documents.

This reduction in the amount of data not only serves as a technical filter, but also as an effort to improve the quality of the analysis. The final dataset obtained can be considered more representative in describing the latest developments (*state of the art*) related to deep learning in education policy. Thus, the results obtained are not only quantitative, but also have substantive validity to be analyzed in more depth.

2. Publication Development Trends

An analysis of publication trends shows a significant increase in the number of documents from year to year, especially from 2023 to 2025. In the initial period (2021–2022), the number of publications was relatively limited, which could be interpreted as an initial exploration phase in the study of deep learning in the realm of education policy.

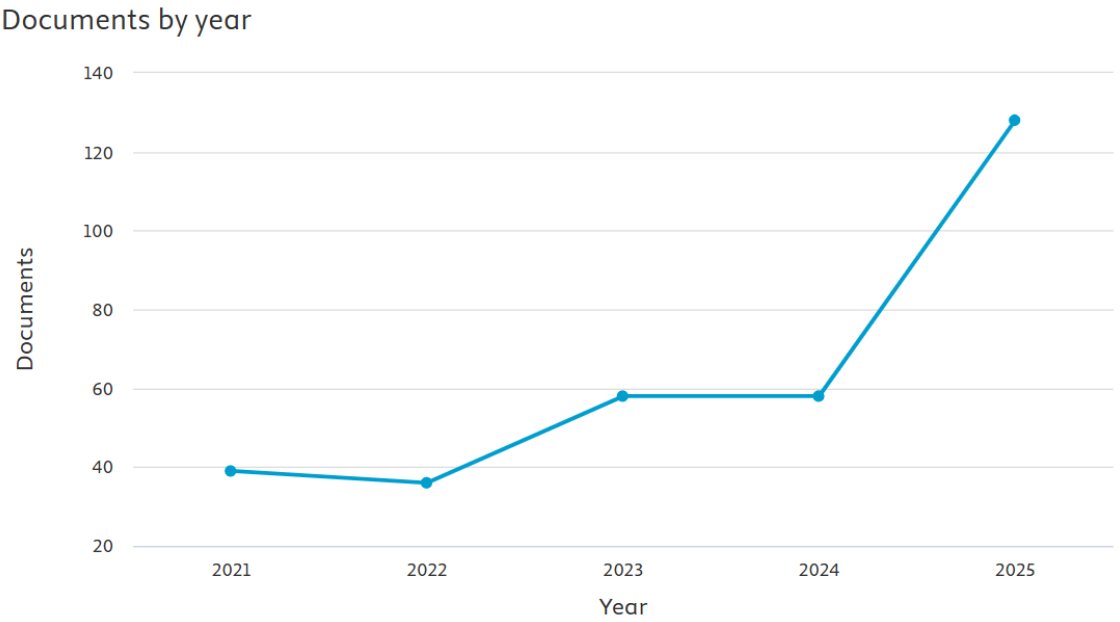

Figure 1: Number of Deep Learning Publications during 2021-2025

Entering 2023, there was a more noticeable increase, which then continued consistently until 2025. This pattern shows an acceleration in knowledge production, which may be influenced by several key factors, such as the rapid development of artificial intelligence technology, the increasing adoption of digital learning systems, and the need for education policies that are able to respond to these changes adaptively.

This increase is also inseparable from the emergence of generative AI-based technologies, such as large language models, which have transformed the way learning, teaching, and evaluation are conducted. Thus, the increasing trend of publications not only reflects the growth in the quantity of research, but also indicates a paradigm shift in the global education system towards a more data-driven and technology-smart approach.

3. Distribusi Publikasi Berdasarkan Negara

Analysis of the distribution of publications by country shows that there is a fairly strong concentration of scientific production in certain countries. Of the total 493 documents, China occupies the highest position with 80 documents, followed by the United States with 56 documents, and the United Kingdom with 39 documents. Furthermore, there are India (20 documents), Australia (17 documents), Hong Kong (13 documents), and Canada and Indonesia which each produced 12 documents. Other countries such as Saudi Arabia are slightly below with 11 documents.

If analyzed proportionally, China's contribution amounts to about 16.2% of total publications, the United States 11.4%, and the United Kingdom about 7.9%. Thus, the top three countries cumulatively account for about 35.5% of the total global publications. This figure shows that more than one-third of knowledge production on this topic is concentrated in just three countries, indicating a geographical dominance in the development of deep learning research in education policy.

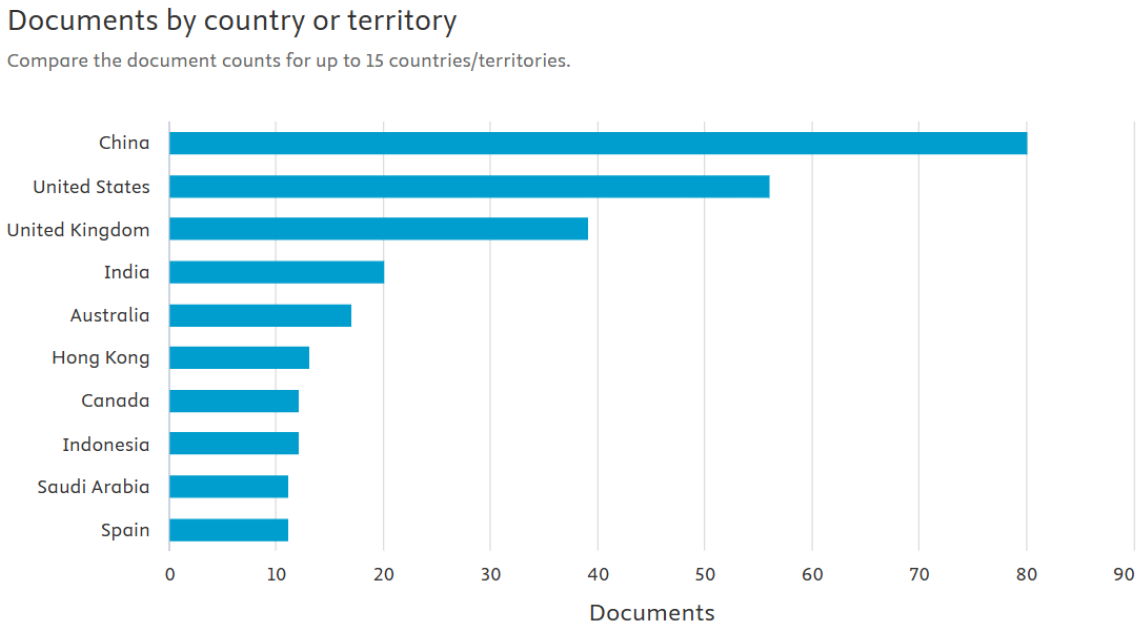

Figure 2: Distribution of publications by country

The gap between China and the United States reached 24 documents, or about 42.8% higher than the United States. This gap is not just a difference in numbers, but reflects the intensity of national policies in encouraging artificial intelligence-based research. China appears to have a more aggressive approach to integrating AI into the education system, thus having a direct impact on scientific productivity. Meanwhile, there was a significant decline after the third place. The UK (39 documents) has a difference of 17 documents with the United States, and India (20 documents) in fact only accounts for about 51% of the number of British publications. This shows the existence of a tiering system in the distribution of global publications, which can be classified into:

a. Dominant groups (China, United States, United Kingdom),
b. Medium group (India, Australia),
c. Emerging groups (Hong Kong, Canada, Indonesia, Saudi Arabia).

Indonesia, with 12 documents, only contributes about 2.4% of the total publications. When compared to China, Indonesia's contribution is only about 15% of China's output, which shows

that there is a fairly wide gap in scientific production capacity. This gap can be attributed to several factors, such as limited research funding, technological infrastructure, and the lack of optimal integration of AI in national education policies.

Interestingly, Canada and Indonesia have the same number of publications (12 documents), although they both have different research capacities globally. It can be interpreted that in the context of the specific topic of deep learning in education policy, contribution opportunities are still open for developing countries to participate more actively.

Overall, the distribution of these numbers not only illustrates who is most productive, but also shows a pattern of global inequality in knowledge production. The dominance of certain countries reinforces the argument that the development of AI-based education technology and policies is still centered on countries with strong innovation ecosystems.

From a research point of view, this condition opens up significant space for further exploration, especially for developing countries such as Indonesia. The relative low contribution is not only a weakness, but also shows that there is a research gap that can be used to produce studies that are contextual, innovative, and relevant to local needs.

4. Distribution by Field of Science

Analysis of the distribution of fields of science shows that out of a total of 319 documents (dataset of analysis results), there is a very clear dominance in several specific disciplines. The field of Social Sciences occupies the highest position with 157 documents, which is equivalent to about 49.2% of the total publications. This figure shows that almost half of all research related to deep learning policy in education is rooted in the perspective of social sciences.

This dominance emphasizes that the discussion of deep learning in education is not only understood as a technological innovation, but more as a social and policy phenomenon. This means that the main focus of research tends to lead to:

a. Implications of education policy,
b. Transforming the learning system,
c. As well as the social impact of the integration of AI technology.

In second place, the Computer Science field produced 83 documents or about 26.0%. When compared to Social Sciences, there is a difference of 74 documents, which means that the contribution of Computer Science is only about 52.9% of Social Sciences. This shows that although deep learning comes from the technical realm, in the context of education, the social approach is more dominant than the computational approach.

Engineering is in third place with 51 documents (16.0%), followed by Medicine with 44 documents (13.8%). The presence of the engineering field shows its contribution to the development of educational technology systems and infrastructure, while the medical field indicates that deep learning is also beginning to be applied in health education, such as clinical simulations and medical data-based learning.

In the next group, there is a more even distribution but with a relatively small contribution, namely:

a. Environmental Science: 23 documents (7.2%)
b. Psychology: 21 documents (6.6%)
c. Arts and Humanities: 20 documen (6,3%)
d. Multidisciplinary: 19 documents (6.0%)
e. Business, Management and Accounting: 18 dokumen (5,6%)

This distribution shows that the topic of deep learning in education has penetrated various disciplines, although its contributions are still complementary. For example, the field of

psychology plays a role in understanding AI-based learning behavior, while the field of business and management is beginning to examine aspects of governance and policy of technology implementation in educational institutions.

In aggregate, the three main fields (Social Sciences, Computer Science, and Engineering) accounted for a total of 291 documents, or about 91.2% of the total publications. This suggests that research on this topic is highly concentrated on three main pillars:

a. social and policy approaches,
b. technology development,
c. and system engineering.

5. Characteristics and Directions of Research

An analysis of the title and focus of the research shows that there are several main themes that develop in the literature. First, research focuses on the application of deep learning in learning systems, including the use of predictive models and learning recommendation systems. Second, research that examines the use of reinforcement learning in teaching strategies, which shows that there are innovations in technology-based pedagogical approaches.

Third, the emergence of studies that focus on aspects of ethics, personalization, and fairness in the use of AI in education. This shows that technological developments are not only responded to technically, but also critically, especially in the context of their impact on access and equality in education. In addition, the emergence of topics related to generative AI, including the use of ChatGPT in learning, indicates a new phase in technology-based education research. The focus of research has begun to shift from just the implementation of technology to the analysis of the impacts, regulations, and policies that govern the use of this technology. Thus, the current direction of research is not only applicative, but also reflective and normative, which seeks to understand how technology can be used responsibly in the education system.

The findings indicate that the global distribution of research on deep learning policy in education is highly uneven, with a strong concentration in countries possessing advanced research and technological infrastructures. The United States, China, and Western European countries emerge as dominant contributors to scientific publications in this field. This dominance reflects not only high academic productivity but also the presence of well-established research ecosystems supported by national policies, funding mechanisms, and artificial intelligence innovation frameworks. The United States, in particular, plays a central role in shaping the global research landscape of deep learning in education (Gupta & Dhawan, 2019; Mao, Li, Zhao, & Zeng, 2018; Pan et al., 2023) .

Meanwhile, the increasing contribution from China and East Asia highlights a shift toward a more multipolar structure in global knowledge production. China has demonstrated significant growth in publication output alongside strong integration between technological development and educational policy. This trend suggests that global research leadership is becoming more distributed, driven by increased investment and international collaboration in artificial intelligence and digital education (Du, Zhu, & Nardo, 2025; Pan et al., 2023). Cross-border collaboration further accelerates research development by facilitating knowledge exchange and innovation.

From a disciplinary perspective, research in this area is predominantly centered on pedagogical applications and competency development. Many studies emphasize the role of deep learning in enabling personalized, adaptive, and learner-centered educational experiences. This aligns with the demands of 21st-century education, which prioritize critical thinking, problem-solving, and self-regulated learning skills (Sergis & Sampson, 2019; F. Zhang, Wang, & Zhang, 2025) . Consequently, deep learning is no longer viewed solely as a technical tool but as a transformative element within educational paradigms.

The integration of deep learning technologies into education is evident in applications such as automated assessment systems, intelligent learning recommendations, and cross-language resource management. These developments indicate a transition toward data-driven and AI-supported educational systems. However, such advancements are accompanied by challenges, including infrastructural limitations, digital literacy gaps among educators, and the misalignment between rapid technological changes and existing educational policies (Abdurakhimova et al., 2025; F. Zhang et al., 2025) .

Despite these advancements, several research gaps remain. One major issue is the conceptual ambiguity surrounding the term “deep learning,” which is often used inconsistently across studies. Most research adopts a cognitive perspective, while affective, social, and contextual dimensions remain underexplored. This highlights the need for a more comprehensive and integrative conceptual framework (Sergis & Sampson, 2019; Winje & Løndal, 2020) .

Issues of equity and accessibility continue to pose significant challenges. The implementation of deep learning in education is constrained in resource-limited settings, such as rural schools and underdeveloped educational systems. These disparities indicate that technology-driven educational transformation is not yet fully inclusive, necessitating more adaptive and context-sensitive policy approaches (Pahrudin, Aridan, & Barata, 2025) .

Another critical gap lies in the limited development of assessment tools capable of measuring deep learning competencies comprehensively. Existing studies tend to focus more on theoretical or technological aspects, while robust and multidimensional evaluation frameworks remain insufficiently explored. This gap presents an important opportunity for future research to develop more relevant and scalable assessment models

In summary, research on deep learning in educational policy has grown significantly and demonstrates strong interdisciplinary characteristics. Nevertheless, conceptual, methodological, and practical challenges persist. Future research should aim to integrate technological, pedagogical, and policy perspectives more comprehensively to produce solutions that are not only innovative but also inclusive and sustainable.

CONCLUSION

This study demonstrates that research on deep learning policy in education has grown significantly in recent years and has emerged as a strategic field in the transformation of global education systems. The bibliometric analysis reveals that knowledge production remains concentrated in technologically advanced countries such as China, the United States, and the United Kingdom. This concentration reflects a global disparity in the development and implementation of deep learning technologies in education. Furthermore, the distribution across subject areas highlights the dominance of social sciences, indicating that deep learning in education is predominantly examined from policy, implementation, and social impact perspectives rather than purely technical dimensions.

This finding reinforces the notion that deep learning is not merely a technological innovation but also a policy-driven and systemic transformation in education. At the same time, this study identifies several critical research gaps, including conceptual ambiguity, limited assessment frameworks for deep learning competencies, technological access disparities, and misalignment between policy and practice. These gaps suggest that despite rapid research growth, substantial opportunities remain for more comprehensive and context-sensitive studies. Overall, this study concludes that integrating deep learning into educational policy is a complex and

multidimensional process that requires interdisciplinary approaches and adaptive, sustainable policy support.

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