# Analisis Bibliometrik Penerapan Deep Learning Dalam Teaching Factory: Tren Publikasi, Kolaborasi, dan Arah Riset 2020–2026

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***Abstrak***

*Penelitian ini bertujuan untuk memetakan perkembangan riset tentang* deep learning *dalam pembelajaran* teaching factory *melalui analisis bibliometrik dan visualisasi jejaring menggunakan VOSviewer. Data artikel diperoleh dari basis data Crossref melalui Publish or Perish dengan menggunakan kata kunci "deep learning" dan "teaching factory" pada judul dan abstrak artikel. Setelah proses seleksi, sebanyak 1.000 dokumen relevan yang diterbitkan pada periode 2020–2026 dianalisis. Hasil penelitian menunjukkan bahwa jumlah publikasi meningkat dari 69 artikel pada tahun 2020 menjadi 263 artikel pada tahun 2025, kemudian menurun menjadi 247 artikel pada tahun 2026, dengan total sitasi sebanyak 567. Analisis kata kunci menunjukkan bahwa tema dominan berkaitan dengan* learning, student, model, implementation, *dan* teaching factory, *sedangkan visualisasi jejaring menunjukkan bahwa hubungan antartopik masih terkonsentrasi pada beberapa klaster utama dan belum membentuk integrasi riset yang kuat. Temuan ini menunjukkan bahwa penelitian tentang* deep learning *dalam pembelajaran* teaching factory *masih berada pada fase pertumbuhan awal, tetapi memiliki potensi yang besar untuk dikembangkan melalui kolaborasi lintas disiplin, penguatan model pembelajaran berbasis AI, dan penerapan penelitian yang lebih kontekstual dalam pendidikan vokasi.*

***Kata kunci:*** *Bibliometric, deep learning, teaching factory, pendidikan vokasi*

***Abstract***

*This study aims to map the development of research on deep learning in teaching factory learning through bibliometric analysis and network visualization using VOSviewer. Article data were obtained from the Crossref database via Publish or Perish using the keywords "deep learning" and "teaching factory" in the article titles and abstracts. After the selection process, 1,000 relevant documents published during the 2020–2026 period were analyzed. The results show that the number of publications increased from 69 articles in 2020 to 263 articles in 2025, then declined to 247 articles in 2026, with a total citation count of 567. Keyword analysis indicates that the dominant themes are related to learning, student, model, implementation, and teaching factory, while network visualization reveals that intertopic relationships remain concentrated within several main clusters and have not yet formed a strong research integration. These findings indicate that research on deep learning in teaching factory learning is still in an early growth phase, but it has substantial potential for further development through cross-disciplinary collaboration, strengthening AI-based learning models, and implementing more context-based research in vocational education.*

***Keywords:*** *Bibliometric, deep learning, teaching factory, Vocational Education.*

## 1. Introduction

The development of digital technology and artificial intelligence has driven significant transformation in vocational education, particularly in learning models that require a direct connection between classroom instruction and industry needs. In this context, the teaching factory approach is relevant because it integrates production-based learning, simulation of real work environments, and the strengthening of competencies in accordance with labor market demands. On the other hand, deep learning, as a branch of artificial intelligence, is increasingly utilized in education to support personalized learning, data analysis, intelligent evaluation, and data-driven decision-making. The combination of these two concepts theoretically has the potential to strengthen vocational learning that is adaptive, contextual, and aligned with industry needs [1][2][3].

Nevertheless, studies that specifically examine the intersection of deep learning and teaching factory remain limited and are scattered across various disciplines. Some research has focused primarily on teaching factory as a vocational learning model, whereas other studies have highlighted the application of deep learning in broader educational contexts or in different technical domains [4][5]. As a result, there is still no comprehensive scientific mapping of research development at the intersection of these two topics, whether in terms of publication trends, collaboration patterns, dominant themes, or future research directions [6][7]. This condition indicates a literature gap that needs to be addressed through a systematic analytical approach.

Bibliometric analysis is an appropriate approach to address this need because it enables the mapping of the intellectual structure of a field based on scientific publication data in an objective manner[8]. Through this approach, researchers can identify publication trends, citation patterns, keyword relationships, and thematic clusters emerging within a particular area of study. Therefore, this study aims to map the development of research on deep learning in teaching factory learning through bibliometric analysis and network visualization. The novelty of this study lies in its specific mapping of the intersection between deep learning and teaching factory using a bibliometric approach based on Crossref data from the 2020–2026 period, with an analysis that not only highlights publication and citation trends but also maps the intellectual structure of the field through co-authorship and keyword co-occurrence analysis using VOSviewer. Unlike previous studies that generally discuss teaching factory or deep learning separately, this study provides a comprehensive picture of thematic relationships, scientific collaboration patterns, and the direction of research development at the intersection of these two topics. Thus, the novelty of this research is not only found in its specific object of study but also in its contribution to revealing the position, patterns, and research gaps that have not been fully mapped in the literature on technology-based vocational education, so that the findings are expected to contribute scientifically to the development of technology-based vocational education and serve as a reference for future research.

## 2. Research Method

This study employed a descriptive quantitative approach using bibliometric methods to map the development of scientific publications on deep learning in teaching factory learning. A bibliometric approach was selected because it enables the objective identification of publication trends, citation patterns, scientific collaboration structures, and dominant themes based on publication metadata. Through this approach, the study was designed to produce a systematic overview of research development, the intellectual structure of the field, and future research opportunities at the intersection of deep learning and teaching factory.

### *2.1 Data Source*

The research data were obtained from the Crossref database accessed through Publish or Perish software. Data retrieval was conducted on article metadata using the keywords “deep learning” OR “teaching factory” in the title and abstract fields of the documents. The publication scope was limited to the 2020–2026 period to ensure that the analysis focused on recent research developments, and from the search and selection process, 1,000 relevant documents were obtained for analysis.

### *2.2 Data Collection Technique*

Data collection was carried out through several systematically arranged stages. The first stage involved defining the research topic and developing a search string in accordance with the study focus, namely "deep learning" OR "teaching factory." The second stage involved searching documents through Publish or Perish based on Crossref, after which the search results were exported into compatible bibliographic formats such as CSV, RIS, or BibTeX to facilitate further processing. The third stage involved data screening based on inclusion and exclusion criteria.

The inclusion criteria comprised journal articles, proceedings papers, or other scholarly documents directly related to deep learning, teaching factory, vocational education, or industry-based learning, and that contained complete bibliographic metadata. The exclusion criteria included non-scholarly documents, documents irrelevant to the research focus, duplicate entries, and publications that did not provide sufficient bibliographic information for bibliometric analysis. Through these stages, the resulting dataset was expected to be more valid, consistent, and representative in describing research development on the topic under study.

### 2.3 *Data Analysis Technique*

Data analysis was conducted bibliometrically with the assistance of VOSviewer software and supporting tabulation in Microsoft Excel. Excel was used to clean, verify, and tabulate the initial metadata, while VOSviewer was used to visually map the relationships among bibliographic elements. The analysis included: (1) publication trends by year of publication, (2) citation patterns to identify the influence level of documents, (3) co-authorship to examine collaboration patterns among authors or institutions, and (4) keyword co-occurrence to identify dominant themes and conceptual relationships.

### *2.4 Research Flow*

The results of the analysis were visualized in three main forms: network visualization, overlay visualization, and density visualization. Network visualization was used to examine the structure of relationships among bibliographic elements, overlay visualization was used to interpret the temporal development of research themes, and density visualization was used to identify the most dominant keywords or research areas in the literature. The results were interpreted by examining patterns of connectivity, cluster strength, keyword frequency, and the temporal direction of theme development. With this procedure, the research methodology was designed to be transparent, replicable, and consistent with the presented analytical results.

## 3. Result and Discussion

### 3.1 Results

#### *3.1.1 Publication Trends*

Based on the search and screening results, this study analyzed 1,000 documents published during the 2020–2026 period with a total of 567 citations. On a yearly basis, the number of publications showed an overall upward trend, from 69 articles in 2020 to 67 in 2021, 91 in 2022, 127 in 2023, 121 in 2024, and peaking at 263 articles in 2025, before slightly declining to 247 articles in 2026. This pattern indicates that the topics of deep learning and teaching factory learning have attracted strong academic attention, although fluctuations are still evident across several observed years.

Figure 1 shows that, when related to citation counts, the trend indicates that an increase in the number of publications does not always correspond directly to the accumulation of scientific influence. Nevertheless, the high number of publications in 2025 and 2026 suggests that this topic is attracting increasing attention within vocational research and educational technology. Accordingly, the state of the art of this topic can be understood as the intersection of artificial intelligence technology, practice-based learning, and the need for adaptive and contextual learning development.

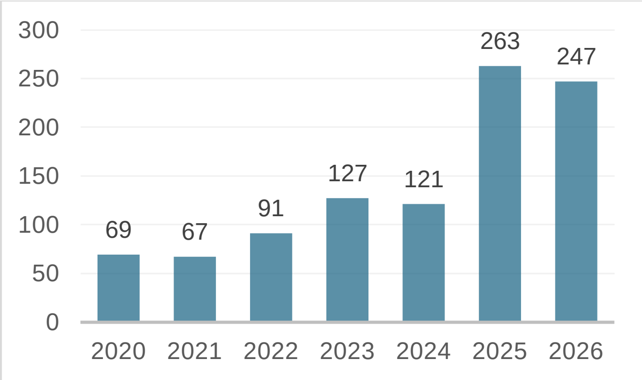


Figure 1. Total Articles on Deep Learning in Teaching Factory Learning, 2020–2026

Conceptually, this condition indicates that deep learning in teaching factory has shifted from being merely a technological discourse to a research topic that is beginning to mature, particularly in the context of learning innovation, data-driven evaluation, and the adaptation of learning to industry needs. However, because citation and publication counts still show fluctuations, this field continues to offer substantial opportunities for more specific, applied, and empirically grounded research.

### *3.1.2 Publication Data and Search results*

The publication data selected for analysis in this study and processed using VOSviewer are presented in Table 1. The top 15 articles with the highest citation counts were used as the sample. The total number of citations across all articles included in this study was 567, as shown in Figure 2.

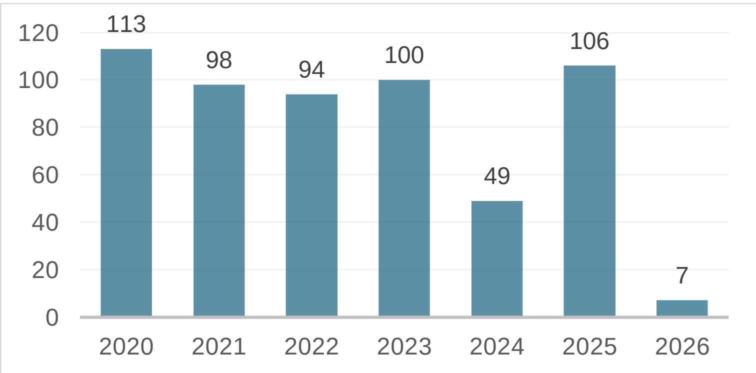


Figure 2. Citation Counts of Deep Learning in Teaching Factory Learning, 2020–2026

Figure 2 shows the citation counts of articles on deep learning in teaching factory learning over the 2020–2026 period. Overall, citation counts fluctuated across the observation period, with 113 citations in 2020, declining to 98 in 2021 and 94 in 2022, then increasing to 100 in 2023. After that, citations dropped sharply to 49 in 2024, rose again to 106 in 2025, and then declined to 7 in 2026. This pattern suggests that scientific influence in this topic does not increase linearly, but is instead shaped by certain years that produced more highly cited documents.

Analytically, this pattern indicates that the state of the art of this topic is still in an active but not yet stable stage of development. The high citation counts in 2020, 2023, and 2025 suggest that, in certain periods, particular works became important references in the discourse on deep learning and teaching factory. Meanwhile, the sharp decline in 2024 and especially

2026 may be interpreted as a decrease in citation impact for newer publications or an uneven level of academic attention to the topic. Accordingly, the state of the art of this topic can be understood as the intersection of artificial intelligence technology, practice-based learning, and the need for adaptive and contextual learning development.

In addition, this citation trend also shows that research on deep learning in teaching factory has not yet reached a point of scientific saturation. This means that there is still considerable room to explore the integration of deep learning into learning design, learning outcome evaluation, and data-driven decision-making. In this context, highly cited studies can be regarded as an initial foundation for shaping the state of the art, while the decline in citations in more recent years further underscores the need to update the literature through approaches that are more current and aligned with developments in educational technology.

Preliminary searches indicate that publications on teaching factory in vocational education have developed and begun to be mapped bibliometrically, both in the context of vocational high schools and broader vocational education. Bibliometric studies on this topic have also been used to map its relationship with entrepreneurship, innovation, and vocational competence strengthening, indicating that the field already has a fairly solid literature base. However, when the focus is narrowed specifically to the application of deep learning in teaching factory learning, the number of identified publications remains relatively limited and tends to be dispersed across adjacent topics, such as artificial intelligence in vocational education, intelligent learning recommendation systems, digital teaching factory learning modules, and adaptive technology integration. This condition suggests that research at the intersection of these two topics has not yet formed a strong scientific cluster and is still in an early stage of development.

From a trend perspective, recent bibliometric studies on teaching factory show growing attention to digital transformation, learning innovation, and the integration of Industry 4.0 technologies in vocational education. On the other hand, research addressing deep learning in education more often emphasizes adaptive systems, pattern recognition, performance analytics, and learning recommendation rather than direct integration into the teaching factory model. These findings indicate that the intersection between deep learning and teaching factory remains more potential than empirically established.

Patterns of scientific collaboration on the teaching factory theme show the dominance of authors and institutions from vocational education, engineering, and curriculum development, with a number of publications originating from Asia and Indonesia. In contrast, research on deep learning in education is more strongly influenced by educational technology, computer science, and intelligent systems. This disciplinary difference explains why cross-field collaboration on deep learning in teaching factory is still not intensive.

Preliminary thematic analysis reveals the emergence of keywords such as teaching factory, vocational education, Industry 4.0, innovation, artificial intelligence, and deep learning as indicators of the direction of research development. Nevertheless, the direct relationship between deep learning and teaching factory has not yet emerged as a dominant theme; rather, it appears in the form of integrative concepts, framework proposals, or innovations in digital learning models. Thus, this topic still offers substantial opportunities for further development through more specific, applied, and vocational education-based research.

### *3.1.3 The Development of Deep Learning in Teaching Factory Learning*

Table 1 presents the 15 most highly cited articles related to deep learning and deep learning in teaching factory learning.

Tabel 1. Publication data on Deep Learning in Teaching Factory Learning

| No | Author | Title | Years | Cites | References |
|---|---|---|---|---|---|
| 1 | Yi Liu, Lei Chen, Zerui Yao | The application of artificial intelligence assistant to deep learning in teachers' teaching and students' learning processes | 2022 | 85 | [9] |

| No | Author | Title | Years | Cites | References |
|---|---|---|---|---|---|
| 2 | Louis Louw, Quintus Deacon | Teaching Industrie 4.0 technologies in a learning factory through problem-based learning: case study of a semi-automated robotic cell design | 2020 | 27 | [6] |
| 3 | Dongjun Ge, Xiaoyue Wang, Jingting Liu | A Teaching Quality Evaluation Model for Preschool Teachers Based on Deep Learning | 2021 | 26 | [10] |
| 4 | Orna Levin | Simulation as a pedagogical model for deep learning in teacher education | 2024 | 24 | [11] |
| 5 | Rishi Kumar, Omkar Patil, Karthik Nath S, Kuldip Singh Sangwan, Rajneesh Kumar | A Machine Vision-based Cyber-Physical Production System for Energy Efficiency and Enhanced Teaching-Learning Using a Learning Factory | 2021 | 26 | [12] |
| 6 | Dian Zhang | Affective Cognition of Students' Autonomous Learning in College English Teaching Based on Deep Learning | 2022 | 21 | [13] |
| 7 | Ruihong Jiang | Understanding, Investigating, and promoting deep learning in language education: A survey on chinese college students' deep learning in the online EFL teaching context | 2022 | 18 | [4] |
| 8 | Dimitris Mourtzis, John Angelopoulos, Nikos Panopoulos | A Teaching Factory Paradigm for Personalized Perception of Education based on Extended Reality (XR) | 2022 | 18 | [14] |
| 9 | Giovanni Lugaresi, Nicla Frigerio, Andrea Matta | A New Learning Factory Experience Exploiting LEGO For Teaching Manufacturing Systems Integration | 2020 | 17 | [7] |
| 10 | E Diwangkoro, Soenarto | Development of teaching factory learning models in vocational schools | | 10 | [15] |
| 11 | Andi Nur Isnayanti, Putriwanti, Kasmawati, Rahmita | Integrasi Pembelajaran Mendalam (Deep Learning) dalam Kurikulum Sekolah Dasar: Tantangan dan Peluang | 2025 | 9 | [16] |
| 12 | Vasilis Siatras, Lydia Athanasopoulou, Kosmas Alexopoulos, Panagiotis Stavropoulos, Dimitris Mourtzis | Applying the Teaching Factory Paradigm and Augmented Reality Technology for Operator Training in Assembly Operations | 2021 | 9 | [17] |
| 13 | Matthias Wolf, Kai Rüdele, Atacan Ketenci, Christian Ramsauer | Design of a Teaching Module for the Determination of Carbon Footprints at Learning Factory Assembly Lines | 2023 | 6 | [18] |

| No | Author | Title | Years | Cites | References |
|---|---|---|---|---|---|
| 14 | Dimitris Mourtzis, John Angelopoulos, Nikos Panopoulos | Development of a Teaching Factory Framework Fusing a Virtual Simulated Machine Shop With The Physical Counterpart For Upscaling Human Machine Interface | 2021 | 6 | [19] |
| 15 | Yuli Rahmawati, Abdul Mu'ti, Suyanto Suyanto, Nur Luthfi Rizqa Herianingtyas | Pembelajaran Mendalam: Transformasi Pembelajaran Menuju Pendidikan Bermutu | 2025 | 6 | [20] |

### *3.1.4 The Visualization of Deep Learning in Teaching Factory Learning*

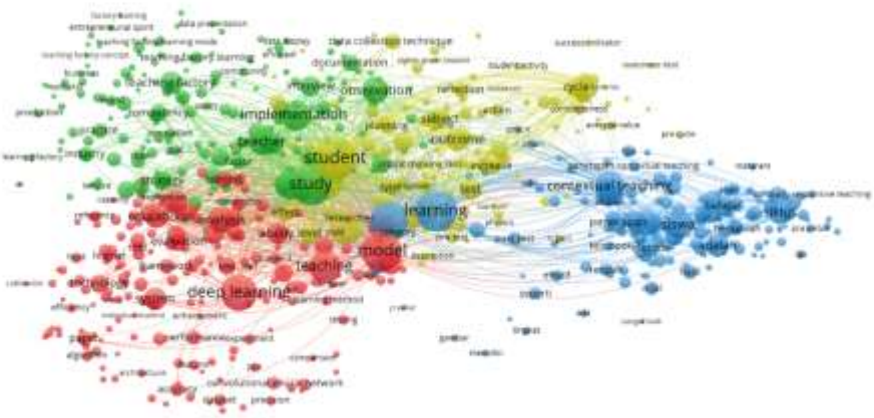


Figure 3. Network Visualization

Figure 3 presents a keyword network map that illustrates the relationships among topics in research on deep learning in teaching factory learning. In general, keywords such as learning, student, study, model, implementation, and teaching factory appear as relatively dominant nodes that serve as bridges across clusters. This indicates that research in this field does not stand in isolation, but is interconnected with themes related to learning, implementation models, learning outcomes, and the vocational education context.

Structurally, the network forms several thematic clusters that reflect diverse research focuses while remaining within a broader common domain. The red, green, blue, and yellow clusters show groupings of topics related to deep learning, pedagogy, learning implementation, and contextual approaches. The presence of the keyword deep learning in close proximity to terms such as model, learning, and teaching factory indicates that this topic is beginning to be integrated into discussions of technology-enhanced learning and educational innovation.

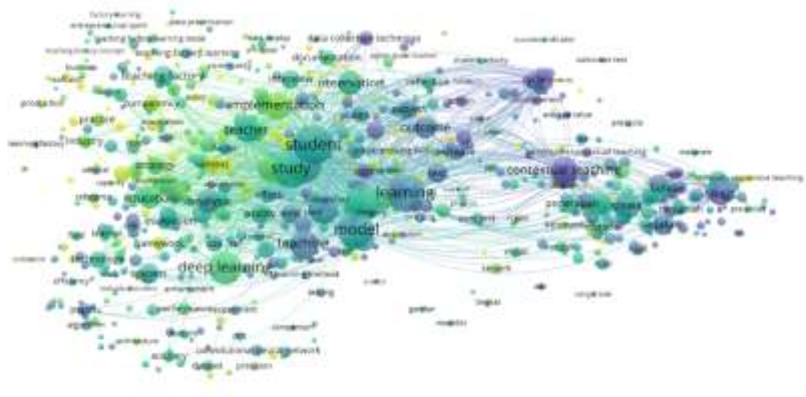


Figure 4. Overlay Visualization

Figure 4 shows the distribution of keyword development according to publication time. The color scheme in the overlay visualization indicates that earlier topics are represented by darker colors, whereas more recent topics appear in brighter colors. Based on this pattern, early studies were more focused on fundamental aspects of deep learning, algorithms, and technical applications, while more recent publications have begun to shift toward integration with teaching factory, contextual learning, and implementation in vocational education settings.

Analytically, the color shift in the overlay visualization indicates an evolution in the direction of research from a technologically oriented approach toward a more applied and pedagogical one. This suggests that deep learning is no longer positioned solely as a computational concept, but is increasingly being situated as part of learning design and educational innovation. Accordingly, the development of this topic reflects a transition from a conceptual focus to an implementation-oriented focus.

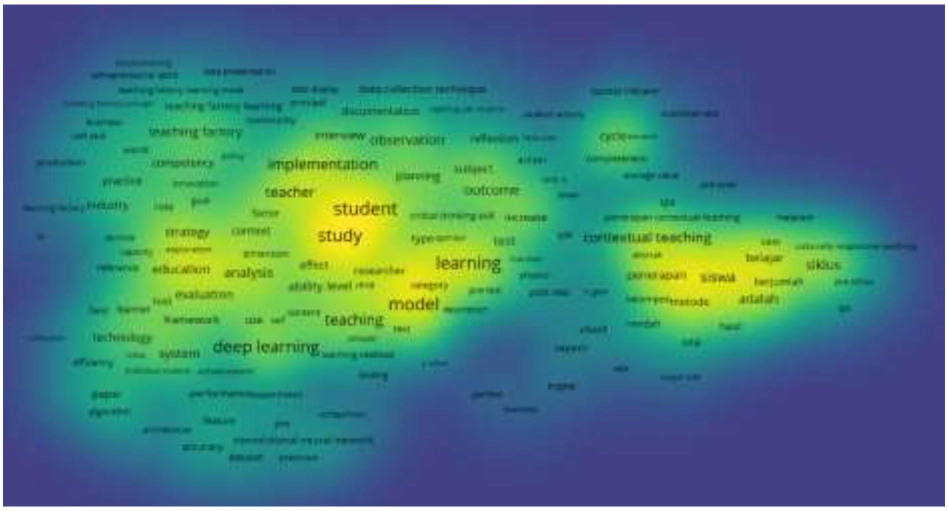


Figure 5. Density Visualization

Figure 5 shows the density or concentration of the analyzed data. Areas with more intense color indicate keywords that appear most frequently and are most densely connected to other topics. In the figure, keywords such as learning, student, study, model, and implementation appear in dense areas, indicating that these terms are central concerns in the analyzed literature. This density suggests that research on deep learning in teaching factory learning is still strongly shaped by core issues of learning, implementation models, and learner engagement.

Overall, the density visualization confirms that the theme of deep learning in teaching factory has not yet been evenly distributed across the research landscape, but remains concentrated around several major themes. This condition indicates that there is still substantial room for further exploration, particularly in developing relationships among deep learning, vocational learning strategies, learning evaluation, and more adaptive educational technology integration. Thus, the density visualization reinforces the finding that this topic is still in an active phase of development and has not yet reached scientific saturation.

### 3.2 Discussion.

The results show that research on deep learning in teaching factory learning is still in an active growth phase, but it has not yet formed a fully stable scientific structure. The rise in publications from 69 articles in 2020 to 263 articles in 2025 indicates growing academic interest, while the decline in 2026 is more appropriately understood as a feature of current-year bibliographic data that has not yet matured. This pattern is consistent with bibliometric studies on teaching factory in vocational education, which also show a shift from conceptual discussions to more applied and innovative themes, although their focus lies more on entrepreneurship and vocational education strengthening [21][22]. Accordingly, the development of deep learning in teaching factory can be read as an extension of the vocational transformation agenda that is increasingly connected to intelligent technologies, but is not yet consolidated as an established domain.

From a citation perspective, the total of 567 citations indicates that the field has received an initial level of scientific recognition, but its impact remains dispersed across documents that do not fully overlap with the two main concepts of the study. The most highly cited articles discuss deep learning in broader educational contexts, intelligent systems, or learning factory rather than the specific integration of deep learning within teaching factory. This is important because it shows that the literature structure is still at the level of conceptual proximity rather than a truly solid thematic integration. This differs from systematic literature review studies on deep learning in education, which show more direct effects on learning outcomes, student engagement, and adaptive learning because their datasets are restricted to articles that explicitly focus on deep learning in education [23][24]. This difference confirms that, in the topic of deep learning in teaching factory, thematic breadth still dominates over depth of integration.

The keyword network visualization also supports this interpretation. Keywords such as learning, student, study, model, implementation, and teaching factory appear as dominant nodes, yet they do not form a highly specific thematic center at the intersection of deep learning and teaching factory. This structure indicates that the analyzed literature still relies on general learning concepts, implementation models, and vocational education. In bibliometric terms, such a pattern commonly occurs when a field is still developing from several adjacent research streams, so its thematic clusters are transitional rather than final. This finding is consistent with [8, who emphasize that keyword mapping and inter-document relationships are useful for identifying the intellectual structure of a growing field, not merely for counting publications.

In the overlay visualization, the shift in themes from technical focus to pedagogical focus is quite clear. Earlier publications tended to emphasize algorithms, computational systems, and technical applications of deep learning, whereas more recent publications increasingly move toward integration with teaching factory, contextual learning, and vocational education environments. This shift suggests that deep learning is no longer seen only as an analytical tool, but as a component of learning design that can strengthen practice-based education. In vocational education, this change is especially important because teaching factory serves as a bridge between schools and industry, so the integration of intelligent technology has the potential to improve work readiness, learning personalization, and data-driven evaluation. Studies on teaching factory implementation in vocational schools also show that effective implementation still depends on curriculum alignment, industry partnerships, facilities, and learning quality, making technologies such as deep learning potentially strategic enhancers when designed appropriately [25][26].

The density visualization shows that the highest concentration remains centered on core keywords such as learning, student, study, model, and implementation. This indicates that the research area is still dominated by basic learning concepts and implementation models rather than highly specific subthemes such as AI-based adaptive assessment in teaching factory, real-time competency monitoring, or learning analytics for vocational production simulations. In vocational education, this condition matters because teaching factory is not merely a teaching model, but a learning ecosystem that requires curriculum integration, teacher roles, industry partners, and student readiness to function effectively across all components, including context, input, process, and product [27][28]. Therefore, these bibliometric findings have clear practical implications: the vocational education field still needs targeted research that connects digital innovation with real learning and workplace needs, rather than simply adopting general technology terminology.

Compared with teaching factory studies that focus on entrepreneurship learning and industry link-and-match, this research broadens the scope by examining how deep learning is entering that discourse. However, unlike vocational studies that use direct samples from schools and teachers to test program implementation, this study shows that the literature is still at an early mapping stage. Its main contribution is therefore not direct program effectiveness testing, but the provision of a thematic map that can guide subsequent implementative research[29]. This is important for vocational education because it offers a clearer direction regarding which themes are already dominant, which are still rare, and which areas are most promising for the development of AI-based learning models.

Methodologically, these results also underline the need for a tighter operational definition of the topic so that the thematic validity of the dataset becomes stronger. Because some highly cited articles are only partially relevant, the interpretation of the findings must remain cautious to avoid overstating the depth of literature integration. In line with bibliometric principles, data selection, metadata cleaning, and precise search string formulation are crucial for the quality of final conclusions[8]. Therefore, the greatest strength of this study lies not only in its visualizations, but also in the precision of its topic definition, dataset consistency, and explanation of its contribution to vocational education.

Overall, the findings indicate that deep learning in teaching factory is a promising field, but it is still in the process of forming a scientific structure. The rise in publications, the emergence of thematic networks, and the increasingly applied direction of development show that the topic is relevant to vocational education transformation, especially in the context of industry-based learning and intelligent technologies. However, because the thematic integration is not yet strong, future research should move from bibliometric mapping toward implementative studies that test how deep learning can truly improve process quality, learning outcomes, and work readiness in teaching factory. In this way, the scientific contribution of the research will not stop at literature mapping, but will extend to strengthening vocational education practice that is more adaptive and evidence-based

## 4. Conclution

This study shows that research on deep learning in teaching factory learning is still at an early growth stage, but it has already demonstrated fairly active development in the scientific literature during the 2020–2026 period. Through bibliometric analysis, this study successfully identified publication trends, citation patterns, and thematic structures, confirming that the integration of deep learning and teaching factory has begun to take shape, although it has not yet evolved into a fully established research cluster. The main contribution of this study lies in providing an initial map of the development of this field, which is academically important for clarifying the direction of future research and practically useful for encouraging the development of vocational learning models that are more adaptive, data-driven, and relevant to industry needs.

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