

Bibliometric Analysis: Trends in Futuristic Pedagogy, Ecopedagogy, and Deep Learning in 21st-Century Education

Yusuf Tri Herlambang*^{}, Yoga Prima Putra^{}, Iim Siti Karimah^{}

Universitas Pendidikan Indonesia, Dr. Setiabudhi St. No. 229, Bandung, West Java, 40154, Indonesia

*Corresponding author, email: yusufth@upi.edu

<https://doi.org/10.17977/um065.v6.i6.2026.9>

Article history

Submitted: 1 May 2026

Revised: 19 May 2026

Accepted: 20 May 2026

Published: 21 May 2026

Keywords

21st century education

Bibliometric analysis

Deep learning

Ecopedagogy

Futuristic pedagogy

Abstract

Twenty-first century education faces complex challenges characterized by rapid technological advancement, globalization, and increasingly urgent environmental crises. These conditions have stimulated the emergence of innovative approaches, such as futuristic pedagogy, ecopedagogy, and deep learning, as responses to the need for more adaptive, sustainable, and meaningful learning. This study aims to analyze trends, developments, and the scientific collaboration landscape related to these three approaches using a bibliometric method. The research data were obtained from reputable scientific databases within the period 2021–2026 and analyzed using bibliometric software to identify publication patterns, dominant keywords, author collaboration networks, and the contributions of countries and institutions. The results reveal a significant increase in the number of publications addressing futuristic pedagogy, ecopedagogy, and deep learning. Furthermore, the findings indicate that developing countries are beginning to show substantial contributions to ecopedagogy studies, while developed countries remain more dominant in technology-based futuristic pedagogy. The collaboration network analysis also demonstrates a growing trend of international cooperation in the field of innovative education. This study provides a comprehensive overview of the direction of contemporary educational research and its implications for future learning practices. The findings are expected to serve as a foundation for the development of educational policies, curriculum innovation, and further research oriented toward inclusive, sustainable, and adaptive education in response to global changes.

1. Introduction

21st-century education is situated within an increasingly complex and disruptive global environment shaped by rapid digital transformation, globalization, socio-cultural shifts, and escalating environmental crises. The expansion of technologies such as artificial intelligence, big data, and automation has not only altered how individual access and process information but has also redefined the nature of knowledge, skills, and learning itself (Karimah et al., 2024; Sutanto & Herlambang, 2025). As a result, education systems are required to transition from static, content-oriented models toward adaptive, innovation-driven paradigms that emphasize flexibility, responsiveness, and relevance to real-world challenges (Fitrah et al., 2025; Aleksieva, 2025; Wang et al., 2024). This transformation underscores the urgency of equipping learners with higher-order competencies, including critical thinking, creativity, collaboration, communication, and digital literacy, alongside the capacity for continuous and self-directed learning (Nurdiana, 2025; Rahim et al., 2025).

Within this evolving landscape, three pedagogical approaches futuristic pedagogy, ecopedagogy, and Deep Learning have emerged as strategic responses to the multidimensional demands of contemporary education. Futuristic pedagogy foregrounds the need to prepare learners for uncertainty and complexity by integrating advanced technologies and fostering anticipatory and innovative thinking (Sukaesih et al., 2025; Ariyanti et al., 2024). Ecopedagogy extends the educational agenda by embedding sustainability, environmental ethics, and social responsibility into learning processes, positioning education as a transformative force in addressing global ecological crises (Misiaszek, 2023; Susilawati et al., 2025). In parallel, Deep Learning emphasizes epistemic depth through meaningful understanding, reflective thinking, and the ability to transfer knowledge across contexts, thereby challenging the dominance of surface-level, memorization-oriented learning practices (Zebua, 2024; Agyeman, 2024). Conceptually, these three approaches are not isolated; rather, they intersect in their shared emphasis on transformation, relevance, and learner-centered meaning-making.

The growing scholarly interest in these domains is reflected in the increasing use of bibliometric analysis to map the development of educational research. Bibliometric approaches have proven effective in identifying publication trends, intellectual structures, and collaboration networks within complex research fields (Irawan,

2024). Prior studies have applied bibliometric methods to examine areas such as artificial intelligence in education, sustainability education, and deep learning pedagogy, revealing expanding research clusters and thematic diversification (Ariyanti et al., 2024; Munandar et al., 2025). Furthermore, studies on ecopedagogy highlight its rising prominence in response to global environmental challenges, while research on Deep Learning pedagogy demonstrates its significant contribution to enhancing higher-order thinking and meaningful learning outcomes (Amir et al., 2025; Harpina et al., 2025). However, these studies remain largely domain-specific and fragmented.

Despite the richness of existing literature, a critical gap persists in the lack of integrative bibliometric analyses that simultaneously examine futuristic pedagogy, ecopedagogy, and Deep Learning within a unified analytical framework. This fragmentation limits the ability to understand how these concepts co-evolve, intersect, and collectively shape the discourse of 21st-century education. Without such integration, the field risks developing in silos, thereby constraining theoretical advancement and the formulation of holistic educational models capable of addressing complex global challenges.

Responding to this limitation, the present study conducts a comprehensive bibliometric analysis that integrates these three pedagogical domains. By employing visualization tools such as VOSviewer and Biblioshiny, this study systematically maps publication trends, keyword co-occurrence, and collaboration networks to uncover the intellectual structure and developmental trajectory of the field (Irawan, 2024). This integrative approach is expected to move beyond descriptive mapping toward a more critical understanding of how these pedagogical paradigms are interconnected.

Accordingly, this study aims to analyze the trends, patterns, and structural relationships of research on futuristic pedagogy, ecopedagogy, and Deep Learning within the context of 21st-century education. Specifically, this study seeks to examine the temporal evolution of research trends, identify dominant themes and keyword interconnections, and explore collaboration networks and knowledge structures that define this field. By doing so, the study contributes not only to bridging the existing research gap but also to providing a more coherent and strategic foundation for future educational research and innovation.

2. Method

This study employed a bibliometric analysis approach to systematically map and analyze research trends related to Futuristic Pedagogy, Ecopedagogy, and Deep Learning in the context of 21st-century education. Bibliometric analysis is widely used to examine the development, structure, and dynamics of scientific literature through quantitative and visualization techniques (Donthu et al., 2021; Ellegaard, 2018).

The data collection process was conducted on March 15, 2026, using the Publish or Perish software developed by Harzing. The data were retrieved from the Crossref database, which provides broad coverage of open-access scholarly metadata and allows efficient extraction of bibliographic information. The selection of Crossref was based on its accessibility, comprehensive metadata coverage, and compatibility with bibliometric tools. However, it is acknowledged that Crossref has limitations compared to databases such as Scopus and Web of Science, particularly in terms of data standardization, citation indexing accuracy, and coverage of high-impact journals.

The search strategy was conducted using a combination of keywords formulated into the following search query: ("futuristic pedagogy" OR "future pedagogy" OR "education 4.0") AND ("ecopedagogy" OR "environmental education" OR "sustainability education") AND ("deep learning" OR "meaningful learning" OR "higher order thinking") AND ("21st century education" OR "education in the 21st century"). This query was designed to ensure comprehensive retrieval of relevant publications while maintaining alignment with the research focus.

The inclusion criteria applied in this study were: (1) documents published between 2021 and 2026, (2) publications categorized as journal articles, conference proceedings, and review articles, (3) documents written in English, and (4) publications with relevance to the themes of futuristic pedagogy, ecopedagogy, and Deep Learning in education. Meanwhile, the exclusion criteria included: (1) incomplete bibliographic data, (2) non-scholarly documents such as editorials, book reviews, or notes, and (3) documents that were not directly related to the research variables.

Following the data collection process, a data cleaning stage was conducted to ensure the quality and consistency of the dataset. This process involved removing duplicate records, standardizing author names and keywords, and normalizing similar terms (e.g., merging variations such as "deep learning pedagogy" and "deep learning approach" into a unified term). This step is essential to avoid bias and ensure accurate visualization results.

The cleaned data were then analyzed using VOSviewer software to generate bibliometric maps. The analysis employed several parameters, including a minimum occurrence threshold of 5 for keyword analysis, a full counting method, and keywords as the unit of analysis. The types of analysis conducted included co-occurrence analysis (to identify relationships between keywords), co-authorship analysis (to examine collaboration networks), and network visualization to explore the structure and density of research topics (Šimová, 2023).

Through this procedure, the study aims to provide a comprehensive and systematic overview of the development of research related to Futuristic Pedagogy, Ecopedagogy, and Deep Learning, as well as to identify emerging trends and potential research directions in the field of 21st-century education.

3. Results and Discussion

In this section, the results and discussion of the study are divided into three parts: cluster analysis, research trends, and research density. The results of the analysis are presented in graphical form to facilitate readers' understanding of the findings. The data matrix obtained from the collection of sources using the Harzing Publish or Perish application presented on Table 1.

Table 1. Data Matrix

| | |
|-------------------|---------------|
| Publication years | 2021-2026 |
| Citation years | 5 (2021-2026) |
| Paper | 1000 |
| Citations | 1223 |
| Cites/year | 244.60 |
| Cites/paper | 1.22 |
| Cites/author | 574.94 |
| Paper/author | 535.79 |
| Author/paper | 2.20 |
| h-index | 16 |
| g-index | 24 |
| hA-index | 8 |

Table 1 shows that within the time span from 2021 to 2026, there are 1.000 articles relevant to the research theme. Overall, there are 1.223 citations within this five-year period, with an average of 244.60 citations per year and 574.94 citations per author. Furthermore, the collected articles have an h-index of 16, a g-index of 24, and an hA-index of 8.

3.1. Cluster Analysis

In this section, the researcher explains the results of the cluster analysis conducted on the literature and articles obtained from the Crossref database. The cluster analysis was carried out using the VOSviewer application, which enables the visualization of clear graphical representations of the clusters identified in this study, namely Futuristic Pedagogy, Ecopedagogy, and Deep Learning in 21st-Century Education (see Figure 1).

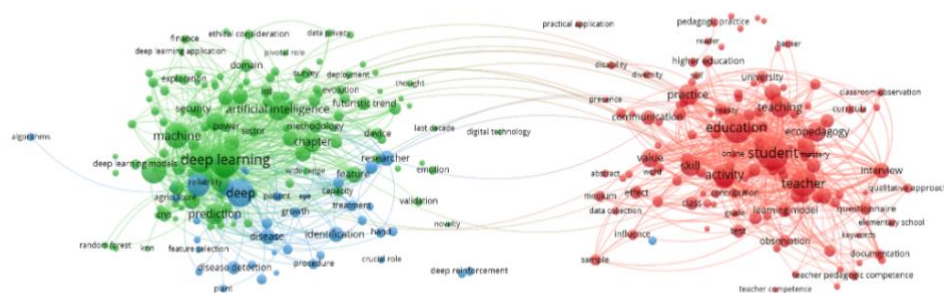


Figure 1. Cluster and Network Visualization

This figure represents a network visualization from the bibliometric analysis, illustrating the relationships among keywords in research related to deep learning, students, and various supporting aspects of education. In this visualization, nodes (points) represent frequently occurring keywords in the literature, while edges (lines) indicate the relationships between keywords based on their co-occurrence in the same documents. Different colors represent clusters formed based on thematic connections.

visualization represent the average year of occurrence of the analyzed keywords, with a time scale shown at the bottom (2023–2026).

The temporal visualization reveals a dynamic evolution of research themes across different periods, reflecting shifts in focus within the educational discourse. The blue color cluster, representing the earlier phase around 2023, is dominated by foundational educational concepts such as education, student, teacher, learning model, activity, and value. The prominence of these keywords indicates that research during this period largely concentrated on core pedagogical structures and classroom practices. Additionally, the appearance of terms such as pedagogic practice, teaching, skill, communication, and higher education suggests that early studies were primarily concerned with strengthening instructional quality and aligning teaching practices with broader educational systems. Analytically, this phase can be interpreted as a consolidation stage, where the emphasis was placed on reinforcing fundamental pedagogical frameworks before the integration of more complex or emerging approaches.

The green color cluster, also emerging around 2023, reflects a transitional phase characterized by the increasing incorporation of technological and analytical dimensions into education. The growing prominence of concepts such as deep learning and machine learning indicates a shift toward data-driven and technology-enhanced learning environments. Keywords such as deep learning models, reliability, and prediction suggest that research began to focus not only on improving learning outcomes but also on ensuring the consistency, accuracy, and sustainability of educational processes. Furthermore, the emergence of terms such as identification and artificial intelligence highlights the expanding role of intelligent systems in diagnosing learning patterns and supporting decision-making in education. This phase signifies a movement from traditional pedagogy toward a more hybrid model that integrates technological innovation with educational objectives.

In contrast, the yellow color cluster, representing the most recent period from 2024 to 2026, illustrates a forward-looking and integrative research direction. The appearance of keywords such as futuristic trend, treatment, ecopedagogy, and deep learning application in brighter colors indicates that these topics are currently at the forefront of scholarly attention and are likely to shape future research trajectories. This cluster reflects a convergence of technological advancement, sustainability concerns, and applied pedagogical innovation. The inclusion of domains such as finance and treatment suggests that educational research is increasingly connected to broader socio-economic and global contexts, emphasizing the relevance of education in addressing complex real-world challenges. Additionally, keywords such as interview and reality indicate a growing emphasis on empirical validation and contextual understanding, highlighting a shift toward more evidence-based and practice-oriented research.

Taken together, this temporal progression demonstrates a clear trajectory from foundational pedagogical concerns, to technological integration, and ultimately toward a holistic and future-oriented educational paradigm. This evolution suggests that contemporary educational research is no longer confined to improving instructional practices alone but is increasingly directed toward integrating sustainability, technology, and real-world applicability into a cohesive framework for 21st-century learning.

3.3. Future Research Directions

In this section, the researcher explains the findings obtained from the density analysis of research on trends in Futuristic Pedagogy, Ecopedagogy, and Deep Learning in 21st-century education. This section also describes the research topics that have been widely explored by scholars in examining these three approaches. In addition, it outlines potential future research directions related to Futuristic Pedagogy, Ecopedagogy, and Deep Learning in 21st-century education. The visualization of this analysis can be seen in the figure 3.

Density visualization is a technique used to display the level of keyword occurrence density within a research domain. Brighter colors indicate areas of high density (keywords that frequently appear and have strong relationships), while darker colors indicate areas of low density or topics that are less frequently discussed. The density visualization reveals a differentiated structure of research intensity, highlighting the relative prominence and maturity of themes within the field.

areas such as practice, methodology, and exploration are identified as low-density topics, indicating that they remain underdeveloped and present opportunities for further investigation.

These findings suggest that while the core of educational research remains grounded in pedagogical interactions, there is a clear shift toward integrating technological innovation and sustainability-oriented approaches. The strong presence of deep learning reflects an increasing emphasis on meaningful and transformative learning processes, whereas the emergence of artificial intelligence and futuristic trends signals a transition toward anticipatory and adaptive education systems. However, the relatively low density of methodological and practical aspects indicates a gap between conceptual development and empirical implementation.

This pattern is consistent with previous studies. Futuristic pedagogy, for instance, has been widely discussed as an approach that promotes future readiness through technological integration and the development of 21st-century competencies (Nemani, 2024; Ng, 2026; OECD, 2020). However, empirical studies reveal that its implementation at the classroom level remains challenging (Bolat, 2024; Diaz et al., 2024; Voogt & Roblin, 2022), supporting the bibliometric finding that practical and methodological dimensions are still limited. Similarly, research on ecopedagogy highlights its importance in fostering ecological awareness, yet often fails to produce sustained behavioral change (Kopnina, 2020; Rozak, 2024). Stevenson et al. (2021) further emphasize that sustainability education requires a transformative and multidimensional approach, which aligns with the need for deeper integration identified in this study.

In the context of deep learning, previous studies confirm its significant contribution to conceptual understanding, knowledge transfer, and the development of global competencies (Fullan et al., 2020; Hattie & Donoghue, 2020; Utomo et al., 2025). However, the bibliometric findings reveal that this approach is still predominantly studied in isolation, without sufficient integration with sustainability and future oriented pedagogical frameworks. This fragmentation is also noted by Leicht et al. (2021), who argue for a more integrated approach to sustainable education. Furthermore, the dominance of studies from developed countries highlights the lack of contextual research, particularly in developing contexts. Scholars such as Tikly (2020) and Dolnicar (2024) emphasize the importance of adapting global educational frameworks to local socio-cultural conditions, which remains a significant gap, especially in the Indonesian context.

3.4. Implications for Educational Research

The findings of this study provide several important implications for the development of educational research. First, there is a need to move beyond fragmented approaches by developing integrative frameworks that combine futuristic pedagogy, ecopedagogy, and deep learning into a coherent model. Such integration is essential to address the multidimensional challenges of 21st-century education, including technological advancement, sustainability, and the need for meaningful learning. Second, future research should prioritize empirical studies that test the effectiveness of these integrated approaches, particularly in measuring cognitive, affective, and behavioral outcomes simultaneously. This is important to bridge the gap between conceptual discourse and practical implementation.

The next implication is there is a strong need for context-based research that incorporates local wisdom and cultural values. In the Indonesian context, integrating local knowledge systems with global frameworks such as Education for Sustainable Development (ESD) can provide more relevant and applicable educational models. Fourth, the development of comprehensive evaluation instruments is necessary to assess learning outcomes holistically. Such instruments should not only measure academic achievement but also capture students' ecological awareness, critical thinking, and future readiness.

3.5. Limitations

Despite its contributions, this study has several limitations. First, the bibliometric analysis is limited to data obtained from the Crossref database, which may not fully represent the entire body of global scientific publications compared to databases such as Scopus or Web of Science. Second, the analysis is constrained by the selected time range (2021–2026), which may exclude earlier foundational studies relevant to the topic. Third, the reliance on keyword-based searches may lead to the omission of relevant studies that use different terminologies. Finally, while bibliometric analysis provides a comprehensive overview of research trends, it does not offer in-depth qualitative insights into the content of individual studies.

4. Conclusion

Based on the results of the bibliometric analysis of trends in futuristic pedagogy, ecopedagogy, and deep learning in 21st-century education, it can be concluded that these three approaches have shown significant development and are gaining increasing attention in global research, particularly during the 2020–2026 period. The rise in the number of publications reflects an urgent need to transform education systems to be more adaptive to technological, social, and environmental changes. Futuristic pedagogy is rapidly developing

alongside the integration of digital technology and artificial intelligence in learning, while ecopedagogy emerges as a response to sustainability issues and the global environmental crisis. Meanwhile, deep learning emphasizes the importance of meaningful, student-centered learning to build deep conceptual understanding. Keyword analysis and collaboration networks also reveal strong interconnections among these three approaches in shaping a holistic and future-oriented educational paradigm. Therefore, the integration of futuristic pedagogy, ecopedagogy, and deep learning represents a strategic direction for the development of 21st-century education. These approaches are not only theoretically relevant but also have practical implications for creating innovative, sustainable learning that can comprehensively address global challenges.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

References

- Agyeman, N. Y. B. (2024). Deep learning in high schools: Exploring pedagogical approaches for transformative education. *Humanika: Kajian Ilmiah Mata Kuliah Umum*, 24(2). <https://doi.org/10.21831/hum.v24i2.71350>
- Aleksieva, L. (2025). Preparing pre-service teachers for the digital transformation of education: Exploring views and strategies. *Education Sciences*, 15(4), 404. <https://doi.org/10.3390/educsci15040404>
- Amir, A. S., Basri, M., Sahril, S., Supriadi, E. K., & Kamaruddin, K. (2025). Traditional knowledge as ecological intelligence: An ecopedagogy study. *PUPIL: International Journal of Teaching, Education and Learning*, 4(2), 438–450. <https://doi.org/10.20319/ictel.2025.424438>
- Ariyanti, A., Herlambang, Y. T., & Muhtar, T. (2024). Urgensi kompetensi pedagogik guru dalam pembelajaran abad ke-21: Studi kritis pedagogik futuristik. *Ideguru: Jurnal Karya Ilmiah Guru*, 10(1), 389–395. <https://doi.org/10.51169/ideguru.v10i1.1417>
- Bolat, Y., & Gençoğlu, S. D. (2024). The integration of 21st century skills into secondary school English classes and the challenges faced by teachers. *International Journal of Contemporary Educational Research*, 11(1), 36–54. <https://doi.org/10.52380/ijcer.2024.11.1.558>
- Choiriyah, M. (2025). Evaluasi pembelajaran berbasis digital: Sistematis terhadap strategi media yang efektif. *Al-Qiyadah*, 2(1), 64–72. <https://doi.org/10.64481/v1tnrv30>
- Díaz, M. M. M. B., Lim, J. R., Iborra, C. P., López, E., Rodríguez, H., López, R., ... Groot, B. (2022). *The power of curriculum to transform education: How education systems incorporate 21st century skills to prepare students for today's challenges*. <https://doi.org/10.18235/0004360>
- Dolnicar, S., & Demeter, C. (2024). Why targeting attitudes often fails to elicit sustainable tourist behaviour. *International Journal of Contemporary Hospitality Management*, 36(3), 730–742. <https://doi.org/10.1108/IJCHM-07-2022-0828>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Entriz, A. N., & Puspitasari, F. F. (2025). Studi literatur: Integrasi teknologi informasi dalam pelatihan guru sebagai upaya meningkatkan kualitas pembelajaran. *Al-Idarah: Jurnal Kependidikan Islam*, 15(1), 62–73. <https://doi.org/10.24042/b2zk9f46>
- Fitrah, M., Sofroniou, A., Yarmanetti, N., Ismail, I. H., Anggraini, H., Nissa, I. C., Widyaningrum, B., Khotijah, I., Kurniawan, P. D., & Setiawan, D. (2025). Are teachers ready to adopt deep learning pedagogy? The role of technology and 21st-century competencies amid educational policy reform. *Education Sciences*, 15(10), 1344. <https://doi.org/10.3390/educsci15101344>
- Fullan, M., Quinn, J., & McEachen, J. (2020). *Deep learning: Engage the world change the world*. Routledge. <https://doi.org/10.4324/9780429026936>

- Haq, E. D., Masdul, M. R., & Larasati, O. (2025). Ecopedagogy-based curriculum innovation to foster environmental sustainability awareness among Indonesian Generation Z. *Khazanah: Journal of Islamic Education and Science*, 1(1), 17–31. <https://doi.org/10.61815/khazanah.v1i1.863>
- Harpina, H., Darfin, S. A., & Kholifatun, U. N. (2025). Science literacy and climate change issues in elementary school science learning as a green education effort. *Journal of Humanities, Social Sciences, and Education*, 1(2), 55–68. <https://doi.org/10.64690/jhuse.v1i2.34>
- Hattie, J., & Donoghue, G. (2020). Learning strategies: A synthesis and conceptual model. *Educational Psychology Review*, 32(3), 579–613. <https://doi.org/10.1080/00461520.2020.1742952>
- Irawan, M. D., Tarigan, M. F. A., & Siregar, Y. H. (2024). *Analisis bibliometrik: Pemetaan tren penelitian menggunakan aplikasi R*. Deepublish.
- Karimah, I. S., Hendriani, A., Ningtyas, P. M., Kusnadi, U., Hendrawan, B., Putra, Y. P., ... Herlambang, Y. T. (2024). Kecerdasan buatan (*artificial intelligence*) dalam pendidikan. *Naturalistic: Jurnal Kajian dan Penelitian Pendidikan dan Pembelajaran*, 8(2), 193–204. <https://doi.org/10.35568/naturalistic.v8i2.4702>
- Kopnina, H. (2020). Education for the future? Critical evaluation of education for sustainable development goals. *Environmental Education Research*, 26(2), 280–291. <https://doi.org/10.1080/13504622.2019.1707832>
- Leicht, A., Heiss, J., & Byun, W. J. (2021). *Issues and trends in education for sustainable development*. Springer. <https://doi.org/10.1007/978-3-319-69902-8>
- Misiaszek, G. W. (2023). Ecopedagogy: Freirean teaching to disrupt socio-environmental injustices, anthropocentric dominance, and unsustainability of the Anthropocene. *Educational Philosophy and Theory*, 55(11), 1253–1267. <https://doi.org/10.1080/00131857.2022.2130044>
- Munandar, A. A., Herlambang, Y. T., & Muhtar, T. (2025). Pedagogik futuristik: Paradigma baru pendidikan dalam membangun generasi emas Indonesia 2045. *Ideguru: Jurnal Karya Ilmiah Guru*, 10(2), 1408–1416. <https://doi.org/10.51169/ideguru.v10i2.1519>
- Nemani, S. (2024). Preparing future-ready students: The role of transformational leadership in equipping students for the 21st-century workforce. *Journal for the Education of Gifted Young Scientists*, 12(4), 181–192. <https://doi.org/10.17478/jegys.1552021>
- Ng, D. F. S. (2026). Redefining successful education: Future-ready learners. In *Handbook of Asian educational innovation towards the futures of education* (pp. 1–23). Springer Nature Singapore. https://doi.org/10.1007/978-981-96-3901-4_26-1
- Nurdiana, N. (2025). Paradigma baru dalam pedagogik: Menyongsong deep learning sebagai pendekatan pembelajaran di Indonesia abad ke-21. *Sindoro: Cendikia Pendidikan*, 17(3), 121–130. <https://doi.org/10.99534/m3ajk814>
- Nurjanah, S., Bedi, F., & Fitri, T. A. (2024). Strategi pemimpin dalam meningkatkan daya saing siswa lulusan di era digitalisasi. *Re-JIEM (Research Journal of Islamic Education Management)*, 7(2), 213–232. <https://doi.org/10.19105/re-jiem.v7i2.15753>
- Nursaya'bani, K. K., Falasifah, F., & Iskandar, S. (2025). Strategi pengembangan pembelajaran abad ke-21: Mengintegrasikan kreativitas, kolaborasi, dan teknologi. *JIIP: Jurnal Ilmiah Ilmu Pendidikan*, 8(1), 109–116. <https://doi.org/10.54371/jiip.v8i1.6470>
- OECD. (2020). *Education in the 21st century: Future-ready learning*. OECD Publishing. <https://doi.org/10.1787/589b283f-en>
- Pramesti, K. D., Meisya, N. I., & Amrillah, R. (2024). Relevansi lulusan perguruan tinggi dengan dunia kerja. *An Najah: Jurnal Pendidikan Islam dan Sosial Keagamaan*, 3(4), 236–243.
- Rahim, N. A., Mydin, A., Mohamad Subri, U. S., & Mohd Nong, S. A. (2025). Connecting the dots: Bibliometric trends in 21st-century learning skills and teacher competencies. *International Journal of Research and Innovation in Social Science*, 8(12). <https://doi.org/10.47772/IJRISS.2024.8120191>
- Rozaq, A., & Zain, M. H. (2024). Transformative Islamic spirituality as an ethical framework for ecological responsibility. *An-Nur International Journal of Islamic Thought*, 2(2), 48–65. <https://doi.org/10.62032/wjtw8116>
- Stevenson, R. B., et al. (2021). Education for sustainability and transformation. *Sustainability Science*, 16, 789–802. <https://doi.org/10.1007/s11625-020-00842-3>
- Sukaesih, S., Herlambang, Y. T., & Muhtar, T. (2025). Urgensi pedagogik futuristik dalam membangun generasi emas Indonesia menghadapi global megatrend 2045. *Ideguru: Jurnal Karya Ilmiah Guru*, 10(2), 1178–1185. <https://doi.org/10.51169/ideguru.v10i2.1460>
- Susilawati, M. P., Puspita, R. D., & Ruqoyyah, S. (2025). *Ekoliterasi: Membentuk calon guru sekolah dasar berwawasan lingkungan*. Indonesia Emas Group.
- Sutanto, T., & Herlambang, Y. T. (2025). Membangkitkan pedagogik futuristik dalam upaya meningkatkan kualitas pendidikan Indonesia. *Naturalistic: Jurnal Kajian dan Penelitian Pendidikan dan Pembelajaran*, 10(1), 36–41. <https://doi.org/10.35568/naturalistic.v10i1.6612>
- Tikly, L. (2020). Education for sustainable development in the postcolonial world. *Compare*, 50(3), 1–17. <https://doi.org/10.1080/03057925.2019.1686642>
- Utomo, J. B., Prayitno, H. J., & Indri, I. (2025). Strategies and development of the deep learning approach in vocational high schools in the era of global computing. *Journal of Deep Learning*, 1–10. <https://doi.org/10.23917/jdl.v1i1.10855>

- Voogt, J., & Roblin, N. P. (2022). A comparative analysis of international frameworks for 21st century competences. *Educational Research Review*, 35. <https://doi.org/10.1007/s10648-021-09625-0>
- Wang, C., Chen, X., Yu, T., et al. (2024). Education reform and change driven by digital technology: A bibliometric study from a global perspective. *Humanities and Social Sciences Communications*. <https://doi.org/10.1057/s41599-024-02717-y>
- Wynda, H. (2025). Transformasi pendidikan tinggi: Mengasah soft skills untuk menjawab tantangan kerja di era Society 5.0. *Jurnal Sains Sosio Humaniora*, 9(1), 91–102. <https://doi.org/10.22437/jssh.v9i1.39000>
- Zebua, N. (2024). Education transformation: Implementation of deep learning in 21st-century learning. *Harmoni Pendidikan: Jurnal Ilmu Pendidikan*, 2(2). <https://doi.org/10.62383/hardik.v2i2.1405>