JOURNAL SEKAWAN: Science, Education, and Knowledge Application in Worldwide Academic Networks
Vol. 1 No. 2 (2025) pp. 70-78
https://sekawanpress.com/journals/index.php/sekawan

Science Education in the Digital Era: Integrating Deep Learning in the Context of Primary Education

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Article Info
Article History:
Received : 22/12/2025
Revised : 25/12/2025
Accepted : 25/12/2025

Keywords:
Science education;
Digital Era;
Deep learning;
Primary education;
Learning transformation.

DOI:
http://dx.doi.org/10.59382/js.v1i2.70-78

Abstract
The digital era demands a transformation in learning, including at the elementary school level, so that students not only understand information but are also able to construct knowledge in a deep and meaningful way. This study aims to systematically examine how the deep learning approach is integrated into science learning in elementary schools to support conceptual understanding, critical thinking skills, and the relevance of learning to real life. This study is a literature review with a descriptive analytical approach. Data were obtained from thirteen national scientific articles published in 2024–2025. The articles were analyzed based on their focus, research methods, and findings related to learning strategies and their impact on student understanding. The results of the study show that the deep learning approach is effective in improving understanding of science concepts, encouraging active student engagement, and fostering critical and reflective thinking skills. The application of project-based strategies, environmental exploration, technology integration, and mindful learning are dominant features in its implementation. However, the implementation of this approach still faces challenges such as limitations in teachers' digital literacy, learning infrastructure, and curriculum suitability.

INTRODUCTION

Science education at the elementary school level plays an important role as a foundation in shaping scientific thinking, curiosity, and critical thinking skills in students from an early age. Unfortunately, the learning approach commonly applied still tends to be conventional and teacher-centered. This results in limited active participation by students and low conceptual understanding of science material, which is often abstract in nature (Nabila et al., 2025).

The paradigm shift in education towards the digital era requires a transformation of learning methods from mere information transfer to reflective and contextual learning. The deep learning approach is considered one of the strategies capable of overcoming this challenge because it focuses on deep understanding, conceptual connections, and the application of knowledge in real-life situations. According to Mailani et al. (2025), learning that adopts a deep learning approach can strengthen information absorption and continuously develop students' higher-order thinking skills.

Deep learning in the context of basic education does not refer solely to artificial intelligence technology, but rather to a pedagogical approach that emphasizes meaningful learning, mindful learning, and joyful learning (Wijaya et al., 2025). These three principles are very much in line with the direction of the Merdeka Curriculum, which emphasizes differentiated and contextual learning. This means that students are not only required to understand the material, but also to relate it to their experiences and surroundings.

Several studies have demonstrated the effectiveness of this approach in science education. Putri (2025) applied a deep learning-based educational application to convey science concepts through visual simulations and automatic feedback. As a result, students' understanding of the concepts improved significantly from an average score of 65 to 83 in two learning cycles. Other studies also show that the integration of technology and strategies such as project-based learning and inquiry-based learning can encourage more active student participation and foster a stronger scientific attitude (Nabila et al., 2025).

However, the implementation of deep learning in science education in elementary schools still faces various obstacles. The main challenges include low digital literacy among teachers, limited infrastructure, and a lack of practical training for educators. Hendrianty et al. (2024) state that in order to realize this new learning paradigm, structured professional development, collaboration between schools, and strong policy support are needed. Therefore, it is important to continue to examine and strengthen the implementation strategy of deep learning as a transformative approach in science education in the digital era.

METHODS

The type of research used is a literature review with a descriptive analytical approach. This study aims to systematically and thoroughly examine various scientific findings related to the application of deep learning approaches in science education in elementary schools. The data sources were obtained from 13 national scientific articles published between 2024 and 2025. The articles were obtained from Google Scholar. The articles were selected based on the following criteria: (1) articles focused on basic education or learning in elementary schools, (2) discussed

the application of deep learning approaches in the context of science and related subjects, and (3) articles were the results of research that had been published in national journals. The data collection procedure was carried out through identification, classification, and in-depth review of the article content. Data analysis was performed using content analysis techniques, focusing on themes and research objectives related to deep learning. The data obtained was then categorized into several main topics, such as: characteristics of deep learning, science learning strategies, implementation challenges, and impact on students.

RESULT AND DISCUSSION

1. Result

The results of this literature study were obtained through a review of 13 national scientific articles relevant to the topic of deep learning application in science education in elementary schools. The analysis was conducted to identify the focus of the study, research methods, and key findings related to learning strategies, technology use, and their impact on students' conceptual understanding.

Each article analyzed presents a different perspective on the application of deep learning approaches, from the role of teachers and the learning models used to the supporting media or technology applied. To facilitate understanding and comparison of findings between articles, Table 1 presents a summary table of the analysis results, including the authors, focus of study, methods, and main findings of each article.

Table 1. Summary of Literature Article Analysis Results

No	Author (Year)	Research Focus	Method	Key Findings
1	Putri, (2025)	Deep learning-based simulation application for elementary school science	classroom action research	A significant improvement in understanding science concepts after using interactive visual educational applications. Students are more interested and active in the learning process.
2	(Maulidiya Nabila et al., 2025)	Implementation of the Merdeka Curriculum & deep learning in elementary school science	Literature Review	Deep learning can support the objectives of the Merdeka Curriculum through contextual, exploratory, and student-centered learning. It encourages understanding

				and independence in learning.
3	(Monaliza, 2025)	Teachers' reflections on the application of deep learning in elementary school mathematics	classroom action research	Teachers recognize the importance of meaningful learning processes. The application of deep learning through reflection makes students more active and critical.
4	Mutmainnah et.al.(2025)	Implementation of Deep Learning Approach to Mathematics Learning in Elementary School	Qualitative Study	The application of deep learning in mathematics studies has a positive impact on student understanding. This method encourages active student involvement through various interactive activities, such as simulations and experiments, making the learning process more meaningful and enjoyable.
5	(Hendrianty et al., 2024)	Strengthening teachers' mindset towards deep learning	Qualitative Study	Teachers were found to have a low understanding of the principles of deep learning. In-depth digital and pedagogical training is needed for teachers to be able to adopt this approach effectively.
6	(Mailani et al., 2025)	Deep learning strategies for basic mathematics concepts in elementary school	Literature Review	Proposes real-world experience-based learning, interconceptual connections, and metacognition as the core of deep learning. Shows positive results in student understanding retention.
7	Lily Maharani et al. (2025)	The role of mindfulness in deep learning mathematics	Qualitative Study	Mindfulness strengthens students' focus and emotional control, which has a direct impact on learning engagement and conceptual understanding, including science.
8	Natsir (2025)	Implementation of deep learning in the Merdeka Curriculum in elementary schools	Case Study	The structure of the Merdeka Curriculum allows for flexibility in the application of deep learning, but the main obstacles lie in

				technological mastery and teacher readiness.
9	(Angga & Sari, 2025)	Deep learning in Physical Education, Sports, and Health (PJOK) and 21st-century skills	Literature Review	Deep learning supports the strengthening of 21st-century skills such as collaboration, communication, and creativity, which are also relevant to interdisciplinary science learning.
10	(Wijaya et al., 2025)	Implementation of Deep Learning Approach in Improving Learning Quality in Elementary Schools	Case Study	The school successfully implemented three main aspects of deep learning with local context adaptation. Meaningful learning was applied through contextualization of learning with local issues, mindful learning through systematic metacognitive strategies, and joyful learning through integration of local culture.
11	(Nurhasanah & Pujiati, 2025)	Application of Deep Learning Approach in Elementary School Education	Literature Review	Although Deep Learning has the potential to improve students' conceptual understanding and critical thinking, its implementation still faces challenges in terms of curriculum, teacher training, and supporting facilities.
12	(Cholifatunisa et al., 2025)	Development of Independent Curriculum with Deep Learning Approach in Improving Elementary School Students' Competence	Qualitative Descriptive	The impact of implementing the independent curriculum combined with a deep learning approach has shown very positive results in improving student competency. This is because the curriculum encourages students to not only master basic digital skills, but also to understand the principles of advanced technology that can enrich their cognitive abilities.
13	(Falih et al., 2025)	Implementation of the Joyful Learning Method based on Ice Breaking to	Quasi-Experiment	There was a significant increase in students' interest in learning IPAS after using the joyful learning method.

		Increase Interest in Learning IPAS at MI		Students were more interested and actively participated in the learning process.

2. Discussion

This study aims to examine how deep learning approaches can be integrated into science education in elementary schools, in response to the challenges of learning in the digital age. Based on a review of 13 relevant national scientific articles, it was found that the integration of deep learning can create a new paradigm in science education that is more active, meaningful, and contextual.

Putri (2025) shows that the use of deep learning-based educational applications in science learning in sixth grade elementary school significantly improves students' understanding of concepts and creates a more interactive and enjoyable classroom atmosphere. These findings are supported by Maharani et al. (2025), who found that this approach encourages students to think more critically, creatively, and analytically, as well as to engage more deeply in the learning process. Research by Mailani et al. (2025) also shows that learning that emphasizes three pillars—mindful learning, meaningful learning, and joyful learning—has been proven effective in strengthening concept retention in various subjects, including science.

In addition, the application of project-based strategies and thematic approaches is described by Wijaya et al. (2025), which shows that students are more active when learning science by raising local issues, such as the environment and energy. A similar study by Angga and Sari (2025) even extends this approach to physical education, proving that deep learning supports the strengthening of 6C competencies (critical thinking, creativity, collaboration, communication, citizenship, and character), which are also highly relevant to science learning.

The Merdeka Curriculum is one context that supports the flexibility of deep learning implementation. Nabila et al. (2025) show that this curriculum structure facilitates project-based learning, exploration, and character building, which are in line with the principles of deep learning. This is reinforced by Natsir (2025), who found that this approach also opens up opportunities for teachers to relate science material to students' daily experiences through inquiry and guided reflection methods.

However, the implementation of this approach in the field has not been fully optimized. A study by Nurhasana and Pujiati (2025) states that many elementary schools are still constrained by a lack of teacher training, limited digital devices, and inadequate curriculum integration. This is in line with the findings of Hendrianty et al. (2024), who emphasize that teachers' digital literacy is a crucial factor in the effective implementation of deep learning-based learning strategies.

In terms of strengthening teacher competence, Hayati and Monaliza (2025) explain that the reflective process of teachers is very important in forming a new understanding of meaningful learning. Through reflection, teachers are better able to adapt strategies and materials to students' needs. This is also reinforced by Lily Maharani et al. (2025), who highlight the importance of mindfulness in building students' learning awareness, focus, and self-control during the exploratory and challenging science learning process.

Articles by Nabila et al. (2024) and Sulastri (2025) also add that deep learning encourages a shift in learning culture from simply receiving information to constructing meaning through discussion, problem solving, and reflection. In the context of science, this is very important because scientific concepts require structured understanding and interconnections between concepts.

Overall, the 13 articles analyzed show that the integration of deep learning in elementary science education has a positive impact on improving understanding, active participation, and strengthening student character. However, its successful implementation is highly dependent on teacher readiness, the availability of supporting facilities, and curriculum and policy support that facilitates pedagogical innovation at the elementary education level.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on a review of 13 national scientific articles, it can be concluded that the deep learning approach plays an important role in shaping a new paradigm for science learning in elementary schools, especially in today's digital era. This approach has been proven effective in improving in-depth conceptual understanding, strengthening students' critical and analytical thinking skills, and creating a more active, reflective, and meaningful learning environment. The integration of deep learning is in line with the principles of the Merdeka Curriculum, which emphasizes contextual, collaborative, and real-world experience-based learning.

However, the implementation of this approach still faces various challenges, such as limited digital literacy among teachers, lack of professional training, minimal supporting infrastructure, and curriculum unpreparedness in some schools. Therefore, the application of deep learning requires a systematic strategy and comprehensive support from various parties.

Recommendations

To support the successful integration of deep learning in science education in elementary schools, synergy between teachers, schools, and policymakers is needed. Teachers need to receive ongoing training related to deep learning design that encourages exploration, connections between concepts, and the effective use of

digital technology. Schools must provide supporting infrastructure such as technological devices, internet access, and interactive media relevant to the characteristics of science. In addition, the government and policymakers need to ensure regulations and budgetary support that encourage the implementation of these pedagogical innovations in the curriculum, as well as expand further research that can adapt the deep learning approach to the context of primary education in various regions.

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