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A Deep Learning Approach To 21st Century Skills-Oriented Science Learning: Literature Review

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A B S T R A C T

Students must develop a number of abilities, including critical thinking, creativity, communication, and teamwork, in order to keep up with the advancements in science and technology in the twenty-first century. As a result, scientific education must be creatively tailored to promote the development of 21st-century skills in addition to emphasizing intellectual mastery. Deep learning is one strategy seen to be pertinent to reaching this objective. The goal of this study is to thoroughly examine the idea, traits, and implementation of a deep learning strategy focused on 21st-century abilities. A literature review using a narrative review approach is the methodology employed. Scientific articles published in national and international journals between 2015 and 2025 that were indexed in Google Scholar, Scopus, and ScienceDirect provided the data. Identification phases, screening based on the appropriateness of titles and abstracts, and content analysis based on the research focus were used to choose the literature. The study's findings show that the deep learning technique enhances students' conceptual comprehension, cognitive engagement, and higher-order thinking abilities when learning science. Additionally, by integrating digital technology with problem-based, project-based, and inquiry-based learning paradigms, this method promotes the development of 21st-century skills. However, there are still challenges to its adoption, including the need for more innovative learning designs, teacher readiness, and limited facilities. Therefore, to guarantee the best possible application of deep learning and raise educational standards, support from a variety of stakeholders is required.

INTRODUCTION

The 21st-century advancements in science and technology necessitate that the educational system cultivate critical thinking, creativity, communication, and teamwork abilities in its pupils. These competencies are referred to as 21st-century skills, and they are essential for dealing with global issues and the ever-increasing speed of technology advancements. Because science education emphasizes not just topic mastery but also scientific methods and real-world problem-solving, it is essential to the development of these skills (Hammond et al., 2020). In order to support students' development of profound and significant conceptual knowledge, science education must be creatively constructed (Dormacci and Acar, 2025).

However, learning strategies focused on memory and superficial conceptual comprehension (surface learning) continue to dominate science instruction at all educational levels. This method hinders the development of higher-order thinking skills by encouraging students to merely memorize facts without having a thorough grasp of the connections between ideas. One of the causes of students' poor critical thinking and problem-solving abilities in science is this situation (Kurniawan et al., 2024; Arnold, 2011). Deep learning is one learning strategy thought to be able to solve this problem. Through purposeful, introspective, and student-centered learning activities, deep learning places an emphasis on in-depth conceptual knowledge. This method encourages students to make connections between new ideas and what they already know, evaluate information critically, and apply ideas in a range of real-world situations. Deep learning can enhance conceptual comprehension, critical thinking, and problem-solving skills in science education, according to research (Fullan, 2017; Biggs et al., 2022).

Because the deep learning approach places a strong emphasis on learning activities that demand active student participation in the learning process, it is directly related to the development of 21st-century skills. Deep learning-focused instruction gives pupils the chance to investigate, debate, and reflect, which helps them build higher-order thinking abilities (Zebua, 2025). Additionally, incorporating a deep learning approach into science instruction might improve students' comprehension of topics and their capacity to apply what they have learned to novel contexts.

There are still few research that explicitly integrate a deep learning method with the acquisition of 21st-century abilities, despite the fact that numerous studies have addressed the application of deep learning in science learning. To determine the ideas, traits, and application of deep learning methodologies in scientific education focused on 21st-century abilities, a thorough literature review is therefore required. It is anticipated that this literature evaluation will offer a methodical summary of study advancements and function as a resource for researchers and educators to create more efficient and significant science education.

LITERATURE REVIEW

Deep Learning Theory

In education, deep learning theory refers to a method of teaching that prioritizes meaningful comprehension, active student participation, introspection, and the capacity to relate ideas to real-world situations. Fullan et al. (2017) claim that deep learning promotes students to build knowledge through critical inquiry, teamwork, communication, and problem-solving exercises in addition to memorization. According to Biggs et al. (2022), deep learning happens when students can apply concepts in a variety of contexts, critically assess information, and connect new knowledge to past experiences. Through student-centered learning activities, the deep learning approach in science education promotes the growth of conceptual understanding and higher-order cognitive abilities.

The efficacy of deep learning in enhancing science learning quality and 21st-century abilities is supported by a number of prior studies. According to Ramadhan et al. (2026), deep learning enhances students' problem-solving skills, scientific literacy, and conceptual understanding. According to Baihaqi et al. (2025), through active debate and collaborative learning, deep learning improves critical thinking, creativity, communication, and teamwork abilities. Additionally, deep learning-based training greatly enhances students' evidence-based reasoning and critical thinking abilities, according to Ardhana et al. (2025).

21st-Century Skills Theory

The theory of 21st-century talents highlights the significance of acquiring the abilities required to deal with global concerns and the quick advancement of technology. According to Darling-Hammond et al. (2020), students in the 21st century must possess critical thinking, creativity, communication, collaboration, and digital literacy skills to succeed in modern society. Because science education incorporates inquiry, experimentation, problem-solving, and scientific reasoning, it plays a significant role in the development of these competences, which are also known as the "4C skills."

Previous studies indicate that integrating technology into science learning can strengthen students' 21st-century competencies. Mahyuna et al. (2025) found that STEM learning integrated with deep learning improves collaboration and digital literacy skills. Zuhri et al. (2025) further reported that the use of digital platforms such as Canva, Educaplay, and Augmented Reality (AR) supports communication, creativity, collaboration, and critical thinking. Through deep learning-oriented instruction, students are encouraged to actively participate in collaborative investigations and contextual learning experiences that foster critical and creative thinking.

METHODOLOGY

In order to investigate the use of the deep learning technique in scientific education with a focus on 21st-century skills development, this study used a literature review with a narrative review approach. To have a thorough grasp of the idea, traits, and application of the deep learning methodology in scientific education, a variety of pertinent research findings were integrated using the

narrative review method. Using a variety of accessible literature sources, this method allowed researchers to integrate research findings both descriptively and interpretively (Ferrari, 2015).

Scientific articles pertinent to the research issue that were published in national and international journals served as the study's data sources. Several scientific databases, such as Google Scholar, Scopus, and ScienceDirect, were used for the literature search. The following search terms were used: "deep learning," "deep learning approach," "science learning," "science education," "21st-century skills," "critical thinking," "creative thinking," and "higher-order thinking skills." The selected articles were published within the last ten years (2015–2025) to ensure the recency of the sources used.

This study's inclusion criteria were as follows: (1) research and review articles about deep learning approaches in science education; (2) articles about the development of 21st-century skills like creativity, critical thinking, communication, and teamwork; (3) articles published in peer-reviewed scientific journals; and (4) full-text articles. Articles that didn't mention deep learning techniques, weren't relevant to scientific education, and weren't available in full text were among the exclusion criteria.

Finding articles based on keywords and titles, screening articles based on abstracts, and carefully examining the substance of publications that support the research objectives were all steps in the literature selection process. The concept of the deep learning approach, the features of deep learning-based learning, the learning strategies employed, and the 21st-century skills developed in science learning were the main themes of the qualitative analysis of the articles that satisfied the criteria.

Descriptive qualitative methods were used to evaluate the data, comparing and interpreting study findings from different sources of literature. In order to give a methodical overview of the function of deep learning methodologies in 21st-century skills-oriented scientific learning, the analytical results are then presented in narrative style. This narrative review method allows researchers to flexibly and thoroughly synthesize the literature, thus providing a conceptual foundation for further research (Snyder, 2019).

RESEARCH RESULT

According to the literature study, 18 studies showed how important deep learning techniques are for raising the standard of science instruction and fostering the development of 21st-century skills. Improvements in conceptual comprehension, critical thinking abilities, teamwork, digital literacy, and the use of technology in education are among these findings. Additionally, a number of studies identified obstacles to deep learning implementation, including the requirement for creative learning designs, instructor readiness, and facility constraints. Table 1 provides an overview of the research results from these different sources.

Table 1. Literature Review Results on Deep Learning Approaches in Science Learning and 21st-Century Skills-Oriented

No	Author	Year	Article Title	Research Result
1	Ramadhan, H., Saputro, S., Mahardiani, L., Jati, M. A., & Potabuga, T. I.	2026	Enhancing Students' Scientific Literacy through *Deep learning*: A Systematic Review of Science Learning Models	Deep learning enhances students' conceptual understanding, independent exploration, reflection, and problem-solving skills.
2	Andayanie, L. M., Adhantoro, M. S., Purnomo, E., & Kurniaji, G. T.	2025	Implementation of *Deep learning* in Education: Towards Mindful, Meaningful, and Joyful Learning Experiences	The deep learning approach shifts instruction from teacher-centered to student-centered.
3	Putri, Z. A., & Sumartiningsih, S.	2025	Discovery Learning: Meningkatkan Keterampilan Berpikir Kritis dan Literasi Sains Siswa SD pada Mata Pelajaran IPAS	Inquity learning, Problem-Based Learning (PBL), Project-Based Learning (PjBL) are excellent ways to apply deep learning to develop knowledge via practical experience.
4	Ulumiyah, D., & Pratama, M. A.	2025	Literasi Sains Siswa Sekolah Dasar Melalui Pendekatan Pembelajaran Mendalam (*Deep Learning*).	This approach enhances students' conceptual understanding and scientific process skills.

5	Zain, M., & Akbar, M. S.	2025	Pemanfaatan *Deep learning* dalam Kurikulum Pembelajaran Abad 21: Sebuah Tinjauan Literatur	Deep learning technology creates personalized learning tailored to students' needs and pace.
6	Coelho, O. B., & Silveira, I. F.	2017	*Deep learning applied to Learning Analytics and Educational Data Mining: A Systematic Literature Review*	Deep learning can analyze student learning patterns so teachers can provide timely interventions.
7	Yunita, L., & Mandasari, N.	2025	Pendidikan Sains Berorientasi Keterampilan Abad 21 dalam Konteks Pendidikan Tinggi: Review	Key challenges include limited facilities, teacher training, and resistance to curriculum changes.
8	Baihaqi, M. A., Prayitno, H. J., Ishartono, N., Hamranani, S. S. T., Putra, C. A., & Nizaar, M.	2025	Reimagining 21st-Century Higher Education: A Literature-Based Exploration of *Deep learning* for Cognitive, Social, and Emotional Skill Development	Deep learning enhances critical thinking, creativity, communication, and collaboration through discussions and group work.
9	Azzahra, M. Z., Nawahdani, A. M., & Falani, I.	2024	The Relationship Between Science Process Skills and 21st Century Skills in Science Learning: Systematic Literature Review	This approach supports observation, classification, data interpretation, and inference through digital technology.

10	Ardhana, D., Fajrina, S., & Fitri, R.	2025	Implementasi Problem Based Learning Berbasis *Deep learning* untuk Meningkatkan Berpikir Kritis Siswa pada Materi Sistem Ekskresi di SMA	The deep learning approach enhances critical thinking and evidence-based problem-solving skills.
11	Seviardini, S., Faradita, M. N., & Naila, I.	2026	Pengaruh Pendekatan *Deep learning* Terhadap Kemampuan Berpikir Kritis Peserta Didik pada Pembelajaran IPA Sekolah Dasar	Students are better able to analyze information and draw scientific conclusions.
12	Mahyuna & Saminan, Nurul & Putri, Deviyani.	2025	Integrating *Deep Learning*-Based STEM Education to Enhance 21st-Century Skills Among Generation Z	It enhances student collaboration and digital literacy as 21st-century skills.
13	Naim, C.L., & Rahmi, F. O.	2025	Pembelajaran Berbasis *Deep learning*: Sebuah Kajian Literatur Sistematis	It increases student motivation, engagement, and HOTS, but depends on teacher preparedness and learning design.
14	Maelasari, N., & Lusiana, L.	2025	Efektivitas *Deep learning* dalam Pembelajaran: Sebuah Kajian Systematic Literature Review (SLR)	Deep learning enhances student participation, collaboration, and data-driven adaptive learning.

15	Ikhsan, R. N., & Setiawan, A.	2025	*Deep learning*: Adaptive Solutions Towards Inclusive 21st Century Education	Collaborative projects and digital technology support the participation of students from diverse backgrounds.
16	Yulita, Y., Mawardi, M., Christi, S. R. N., & Akbar, A.	2025	*Deep learning* pada Pembelajaran Sekolah Dasar: Upaya untuk Mempromosikan Kemampuan Berpikir Kritis	PBL and discovery learning enhance students' critical thinking and scientific literacy.
17	Zuhri, A. S., Muslikhah, U., & Samino, S.	2025	The *Deep learning* Approach in 21st Century Education	Canva, Educaplay, and AR enhance communication, creativity, collaboration, and critical thinking.
18	Luthfiyah, H., Nusantara, T., Faizah, S., & Kusumaningrum, S. R.	2025	Implementation of *Deep learning* in Elementary School Improving the Effectiveness and Quality of IPAS Learning	Metacognitive strategies support mindful learning, and local culture fosters joyful learning.

DISCUSSION

The Deep Learning Approach's Concept in Science Education

In-depth conceptual knowledge, active student participation, and the capacity to relate scientific ideas to practical contexts are all highlighted by the deep learning approach to science education. This method, which is focused on meaningful learning, strengthens conceptual comprehension by encouraging students to investigate, consider, and resolve issues on their own (Ramadhan et al., 2026). Additionally, the learning paradigm is changed from a teacher-centered to a student-centered approach through deep learning-based learning (Andayanie et al., 2025).

Deep learning can be combined with a variety of learning methods in contemporary science education, including problem-based learning, project-based learning, and inquiry-based learning, which allow students to build knowledge via practical experience (Putri & Sumartiningsih, 2025). This

approach has been shown to improve conceptual understanding and scientific process skills, which are essential components of science learning (Ulumiyah & Pratama, 2025).

Additionally, the use of deep learning in science education is strengthened by advancements in educational technology. Because deep learning-based learning technology can customize activities and materials to each student's needs and learning style, it makes learning more individualized (Zain & Akbar, 2025). Teachers can provide timely learning interventions and enhance student learning outcomes by using deep learning in educational data mining to analyze student learning patterns more accurately (Coelho & Silveira, 2017).

However, research indicates that there are still a number of barriers to the use of deep learning approaches in science education, including inadequate infrastructure and facilities, a lack of teacher preparation, and opposition to curriculum modifications and traditional teaching methods (Yunita & Mandasari, 2025). This implies that the readiness of the educational system as a whole is just as important to the success of deep learning implementation as the learning model employed.

Deep Learning and 21st-Century Skills Development

The development of 21st-century skills, such as critical thinking, creativity, communication, and teamwork, is closely associated with deep learning methodologies, according to a review of the research. By giving students the chance to participate in group projects, conversations, and problem-solving, immersive learning promotes the best possible development of higher-order thinking abilities (Baihaqi et al., 2025).

21st-century skills must include science process abilities including observation, classification, data interpretation, and inference. By utilizing data and digital technology that promote computational thinking and scientific analysis, immersive learning approaches can aid in the development of these skills (Azzahra et al., 2024). Thus, students' scientific thinking abilities are strengthened and their conceptual understanding is improved through immersive learning-based science instruction.

According to research, immersive learning strategies can greatly enhance students' critical thinking and problem-solving abilities since they teach them how to evaluate data, formulate ideas, and reach conclusions supported by scientific data (Ardhana et al., 2025; Seviardini et al., 2026). Additionally, it has been demonstrated that combining immersive learning with STEM methods improves students' digital literacy and teamwork, two crucial 21st-century abilities (Mahyuna et al., 2025).

Other research shows that deep learning-based instruction can increase student engagement, motivation, conceptual understanding, and higher-order thinking skills. However, teacher readiness and the caliber of the learning design employed have a significant impact on this strategy's efficacy (Naim & Rahmi, 2025). Additionally, it has been demonstrated that deep learning promotes more adaptive and data-driven learning, fosters cooperation, and increases student involvement in the learning process (Maelasari and Lusiana, 2025).

Additionally, the deep learning method holds a great deal of promise for inclusively developing 21st-century abilities. Students with a variety of backgrounds and learning styles can actively participate in the educational process because to the combination of project-based learning, collaborative learning, and digital technology (Ikhsan & Setiawan, 2025).

Using Deep Learning in Science Education

There are several ways to apply the deep learning approach in science education, according to the findings of the literature review. creative education. Because they entail contextual exploration and problem-solving activities, learning models like problem-based learning and discovery learning have been shown to enhance students' scientific literacy and critical thinking abilities (Yulita et al., 2025).

Furthermore, the integration of digital technology in science learning is also an important strategy in implementing deep learning. Research shows that the use of digital media such as Canva, Educaplay, and Augmented Reality (AR) tecnology can help develop students' communication, creativity, collaboration, and critical thinking skills (Zuhri et al., 2025). A paradigm shift in education toward student-centered learning is also shown by this incorporation of digital technologies.

The implementation of a deep learning approach can also be adapted to the local learning context. Research shows that meaningful learning can be achieved by linking learning materials to real-world problems in the students' environment. Furthermore, according to Luthfiyah et al. (2025), metacognitive strategies can be used to develop mindful learning, while the integration of local culture can create joyful learning.

The literature review generally shows that the deep learning approach has a great deal of promise to raise the standard of science education. Students' conceptual comprehension, learning engagement, and 21st-century skills can all be improved using this method. However, the implementation of the deep learning approach still requires support in the form of improving teacher competency, providing learning resources, and developing learning designs that are tailored to student characteristics.

CONCLUSIONS AND RECOMMENDATIONS

Through in-depth conceptual understanding, active student engagement, and the development of 21st-century skills like critical thinking, creativity, communication, and collaboration, the deep learning approach significantly improves the quality of science education, according to a review of the literature. By integrating problem-based learning, project-based learning, and inquiry learning models backed by digital technology, this method promotes a change from teacher-centered to student-centered learning. However, there are still issues with its implementation, including a lack of resources, teacher readiness, and the requirement for student-centered learning approaches. To guarantee the best and long-lasting use of deep learning in science education, it is advised that teacher preparation be enhanced, sufficient facilities and infrastructure be supplied, adaptive curricula be produced, and school policy support be created.

ADVANCED RESEARCH

Suggestions for further research include conducting empirical or experimental studies on the effectiveness of deep learning approaches across various educational levels and science subjects. Furthermore, the influence of teacher preparedness, digital technology use, and the learning environment on the success of deep learning implementation in the classroom could be examined.

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