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Integration of Neuroscience Principles in Science Learning Media: A PICO-Based Systematic Literature Review

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Informasi Artikel	Abstract
E-ISSN : 3026-6874 Vol: 4 No: 1 January 2026 Page : 20-29 Keywords: Neuroscience Elementary Schools Science Learning	Science education at the elementary school level plays a crucial role in fostering scientific thinking, curiosity, and problem-solving skills from an early age. Nevertheless, science instruction in elementary schools often remains teacher-centered, verbalistic, and insufficient in promoting meaningful scientific literacy. In response to these challenges, neuroscience provides a theoretical and empirical foundation for designing learning media that align with how the brain processes, stores, and retrieves information. This study aims to systematically examine the integration of neuroscience principles into science learning media and their effects on elementary students' scientific literacy. A Systematic Literature Review (SLR) was conducted using the PICO framework (Population, Intervention, Comparison, Outcome). Relevant peer-reviewed studies published between 2019 and 2024 were retrieved from Scopus, Google Scholar, ERIC, and DOAJ databases. The review followed four stages: identification, selection, quality appraisal, and thematic synthesis. The results indicate that neuroscience-based interventions—such as Augmented Reality (AR), Brain-Based Learning (BBL), interactive multimedia, and multisensory instructional strategies—consistently improve students' motivation, attention, conceptual understanding, critical thinking, and scientific literacy compared to conventional instructional approaches. The novelty of this study lies in its systematic synthesis of neuroscience-based science learning media through a PICO-oriented framework, highlighting the interaction between cognitive, affective, and technological dimensions of learning. The findings provide important implications for science education, particularly in guiding the development of neuroscience-informed learning media and instructional designs to enhance scientific literacy in elementary schools.

Abstrak
Pendidikan sains di tingkat sekolah dasar memainkan peran penting dalam menumbuhkan pemikiran ilmiah, rasa ingin tahu, dan keterampilan pemecahan masalah sejak usia dini. Namun demikian, pengajaran sains di sekolah dasar seringkali masih berpusat pada guru, verbalistik, dan tidak cukup untuk mempromosikan literasi ilmiah yang bermakna. Menanggapi tantangan ini, ilmu saraf menyediakan landasan teoritis dan empiris untuk merancang media pembelajaran yang selaras dengan cara otak memproses, menyimpan, dan mengambil informasi. Studi ini bertujuan untuk secara sistematis meneliti integrasi prinsip-prinsip ilmu saraf ke dalam media pembelajaran sains dan pengaruhnya terhadap literasi ilmiah siswa sekolah dasar. Tinjauan Pustaka Sistematis (SLR) dilakukan menggunakan kerangka kerja PICO (Populasi, Intervensi, Perbandingan, Hasil). Studi-studi yang relevan dan telah ditinjau oleh rekan sejawat yang diterbitkan antara tahun 2019 dan 2024 diambil dari basis data Scopus, Google Scholar, ERIC, dan DOAJ. Tinjauan ini mengikuti empat tahap: identifikasi, seleksi, penilaian kualitas, dan sintesis tematik. Hasil penelitian menunjukkan bahwa intervensi berbasis ilmu saraf—seperti Augmented Reality (AR), Pembelajaran Berbasis Otak (BBL), multimedia interaktif, dan strategi pembelajaran multisensori—secara konsisten meningkatkan motivasi, perhatian, pemahaman konseptual, berpikir kritis, dan literasi ilmiah siswa dibandingkan dengan pendekatan pembelajaran konvensional. Keunikan penelitian ini terletak pada sintesis sistematis media pembelajaran sains berbasis ilmu saraf melalui kerangka kerja berorientasi PICO, yang menyoroti interaksi antara dimensi kognitif, afektif, dan teknologi dalam pembelajaran. Temuan ini memberikan implikasi penting bagi pendidikan sains, khususnya dalam memandu pengembangan media

pembelajaran dan desain pembelajaran yang berlandaskan ilmu saraf untuk meningkatkan literasi ilmiah di sekolah dasar.

Kata Kunci: Neuroscience, Elementary Schools, Science Learning

INTRODUCTION

Natural Science Education (IPA) at the elementary school level has an important role in forming the basis of scientific thinking skills, fostering curiosity, and developing problem-solving skills from an early age. Science learning is expected to be able to equip students with the ability to understand natural phenomena logically and systematically. However, the reality of science learning in elementary schools still faces various obstacles, such as low student involvement in the learning process, the dominance of verbalistic learning methods, and the use of learning media that has not been able to stimulate students' thinking activities optimally. This condition has an impact on the low quality of the science learning process and outcomes.

Science learning in elementary school has a strategic role in building students' science literacy from an early age. Science literacy includes not only mastery of scientific concepts, but also the ability to think critically, solve problems, and make science-based decisions. However, science learning is still often perceived as a difficult, abstract, and demanding subject rather than understanding concepts in a meaningful way (Sari, et al, 2021). This situation shows that there is a gap between the science learning objectives and the learning practices that take place in the classroom.

In line with the development of science, neuroscience offers a new perspective in designing learning that suits the way students' brains work. Neuroscience is the science that studies the nervous system and brain function, specifically how the brain processes, stores, and manages information during the learning process (rongchae, et al,). Understanding the working mechanisms of the brain is an important foundation in creating an effective, meaningful, and harmonious learning process in line with the characteristics of cognitive development of elementary school-age children.

The results of the latest research show that learning designed based on neuroscience principles is able to increase learning motivation, attention focus, multisensory learning experience, and students' understanding of the subject matter (Adha, 2025). In the context of science learning, the application of neuroscience principles is very relevant because the characteristics of science materials demand visualization, exploration of concepts, and concrete experiences in understanding natural phenomena (Evans, 2024). Therefore, the integration of neuroscience in science learning has the potential to improve the quality of students' learning processes.

However, the integration of neuroscience principles in science learning media in elementary schools has not been carried out optimally. Many teachers do not understand how the working principles of the brain can be applied in the preparation of learning media. As a result, the media used still tends to be textual, passive, and less involved in students' emotions and cognitive activities (Syaflin, 2022). This condition is in contrast to the brain characteristics of elementary school-age children who need visual stimulation, movement, emotional involvement, and direct experience to build meaningful conceptual understanding (Oktafianto, 2025).

The integration of neuroscience principles in science learning media is believed to help students understand concepts more easily and deeply. Learning media designed in harmony with the brain's working mechanisms have the potential to optimize long-term memory, improve attention, and create fun and meaningful learning experiences (Grinting & Fransica Tuah, 2020). There are ten working principles of the brain in learning, including neuroplasticity, the role of emotions in learning, multisensory learning, attention, meaningful and patterned learning, environmental influences, social learning, the importance of sleep and rest, the uniqueness of each brain, and physical activity. In this study, the integration of neuroscience is focused on five main principles, namely neuroplasticity, multisensory, emotion in learning, attention, and meaningful and patterned learning, which is expected to strengthen the science literacy of elementary school students.

Thus, the development of science learning media based on neuroscience principles is a strategic step to improve the quality of science learning in elementary schools so that it is more active, fun, and meaningful in accordance with the way children's brains learn. Although a number of studies have examined the application of neuroscience in science learning, the findings are still scattered and have not been synthesized systematically. Therefore, a Systematic Literature Review (SLR) study is needed to map research trends, the types of learning media developed, and their impact on science literacy. This study uses the PICO framework to formulate the focus of the study in a structured manner, with the aim of systematically analyzing the integration of neuroscience principles in science learning media and its influence on the science literacy of elementary school students

METHOD

This study uses a Systematic Literature Review (SLR) design with a PICO (Population, Intervention, Comparison, Outcome) approach. The SLR method was chosen to obtain a comprehensive and systematic understanding of the integration of neuroscience principles in science learning media and its impact on the science literacy of elementary school students. SLR allows researchers to identify, select, evaluate, and synthesize previous research findings in a structured and replicable manner (Katarya, 2018).

Design and Research Stages

The SLR process in this study is carried out through four main stages, namely identification, selection, quality evaluation, and literature synthesis. The flow of SLR stages refers to a general systematic review procedure that is tailored to the context of educational research, as presented in the SLR process map (Figure 2).

Identification Stage

The identification stage begins with the formulation of research questions using the PICO framework (Higgins et al., 2019). This framework is used to clarify the focus of the study and limit the scope of the study. The components of PICO in this study include: Population, namely elementary school students; Intervention, which is a learning media based on neuroscience principles; Comparison, which is a learning medium or learning strategy without a neuroscience approach; and Outcome, which is science literacy.

Based on this framework, the research questions are formulated as follows: *How effective is neuroscience-based learning media on the science literacy of elementary school students?* At this stage, literature search is carried out through several scientific databases, namely Scopus, Google Scholar, ERIC, and DOAJ. Keywords are organized by PICO components and combined using Boolean operators (AND, OR) to obtain relevant search results. The literature search strategy is carried out using the following English keywords:

("neuroscience-based learning" OR "neuroscience in education")AND ("learning media" OR "instructional media")AND ("science literacy" OR "science achievement")AND ("elementary school") The selection stage is conducted to screen the identified articles to match the focus of the research. The selection process is carried out in stages through checking the title, abstract, and full text of the article, as well as the removal of duplicate articles that appear from various databases.

The inclusion criteria used in this study include: (1) articles from national and international journals that have gone through a peer-review process, (2) articles published in the 2019–2024 range, (3) research that focuses on learning science or science at the elementary school level, and (4) articles that discuss the application of neuroscience principles in learning or learning media. The exclusion criteria include non-journal articles, proceedings without peer review, and research that is not relevant to the context of basic education.

The determination of inclusion and exclusion criteria is also adjusted to the PICO component, including population suitability (SD), clarity of neuroscience-based interventions, the existence of learning comparators, and the relationship of research results with science literacy.

Selection Stage and Inclusion Criteria–Exclusion

Study Quality Assessment Stage

Articles that pass the selection stage are then evaluated for methodological quality to ensure their feasibility as a research data source. Quality assessment is carried out by examining the clarity of the research objectives, the suitability of the research design, the characteristics of the subjects, the procedures for data collection and analysis, and the relevance of the findings to the PICO components. Articles that do not have methodological clarity or do not explicitly link learning interventions to science literacy are excluded from the study. This stage aims to increase the validity and credibility of the results of the literature synthesis.

Stages of Literature Synthesis

The final stage in this study is the synthesis of the literature, which is carried out through narrative and thematic analysis. The synthesis aims to integrate the findings of the selected articles so that a comprehensive picture of the types of neuroscience-based learning media, the principles of neuroscience applied, and their impact on the science literacy of elementary school students.

RESULTS AND DISCUSSION

This stage is carried out to summarize the information from the found keywords that are reviewed based on methods and results, which can be shown in Table.1. The table provides information related to journals that approach studies that are appropriate to the topic through the methods and results achieved.

Table 1. Extract data

Author	Year	Subject	Intervention	Method	Discover
integrtin gAR study	2025	SD	AR neuroscience media	Experiments	Ar experiments based on neuroscience principles showed an increase in motivation and conceptual achievement of elementary school students after using Ar media that emphasized visualization and interaction
Evans et al	2024	SD	Neuroscience-based media	Descriptive	This article describes the procedure for developing neurosans-based teaching materials that are applied

					to elementary school and can be transferred to science
Research Journal	2024	SD	Science innovation media	Literature study	Overview of science media innovation digital story telling pjbl gamifled media with design recommendations that facilitate conceptualization for S students
Amin Harahap	2024	SD	BBL-based Science Module	R&D	The development of BBL-based science modules that show increased involvement and understanding of science concepts for elementary school students.
Research Journal	2024	SD	Science innovation media	Literature study	Overview of science media innovations digital story telling pjbl gamifled media with design recommendations that facilitate conceptualization for elementary school students
Reserchgat E	2025	SD	Concrete Media of Neuroscience	Development	Proceedings/development of reports on the development and implementation of concrete media (magic boxes) based on neuroscience cognitive principles to improve healthy behavior/understanding of multisensory kinesthetic media examples
Konyeme & Alordiah	2024	SD	Neuroscience-based science learning	Qualitative studies	The neuroscience approach supports the development of science concepts
Oktavianto et al.	2025	SD	Neuroscience-based learning	Quasi experiment	Significant effect on critical thinking ability

Cai, S. et al.	2022	SD	AR in science learning	Mixed methods	AR improves students' conception of learning and motivation
Sylvia Lara	2022	SD	Interactive media based on Flash macro media	R&D	The interactive multimedia developed in this study has been proven to be valid, practical, and has a potential effect on student learning outcomes
Ichwan Mudayat	2025	SD	Virtual Lab for cognitive load	Mixed-methods sequential explanatory	students' conceptual understanding in the CLOVL group is higher
Syaflin	2022	SD	Interactive media	Systematic literature review	Interactive media has a positive impact on interest in and understanding of science concepts, but most of them have not referred to
Ainia, et al	2025	SD	Neuroscience-based learning	Quase experiment	Neuroscience-based learning improves learning outcomes because it maximizes emotional activation, attention, and the memory system
Letina & Percovia	2021	SD	Neuroscience-based biology learning	Proceedings / descriptive	Neuroscience-based biology learning improves concept understanding and learning engagement
ResearchGate	2021	SD	Brain-Based Learning in Science	Literature studies	BBL is relevant for basic science learning because it aligns with how the brain works
IJIET	2025	SD	Neuroscience-based AR	Quase experiment	Neuroscience-based AR media improves motivation and science learning outcomes
Saeed & Kayani	2025	SD	Brain-Based Learning	Quase experiment	BBL improves science critical thinking skills
Hendrizal et al.	2025	SD	Neuroscience strategies (multisensory, mnemonics	Literature review	Brainwork-based strategies improve attention and retention; Also influenced by sleep and nutrition

Evans et al.	2023	Students	Cognitive Load Theory is associated with Self-Determination Theory	Theoretical & empirical studies	Cognitive load is closely related to autonomic motivation; Learning designs that reduce cognitive load support intrinsic motivation
Damayanti & Yuliana	2023	Early childhood	Nursery rhymes & media digital (Dual Coding)	Quase experiment	Dual Coding through songs and visuals significantly improves vocabulary mastery

The results of synthesis from various studies show that the neuroscience approach in elementary school science learning consistently has a positive impact on motivation, conceptual understanding, science literacy, and critical thinking skills of students. Various forms of intervention identified include Augmented Reality (AR)-based media, Brain-Based Learning (BBL), neuroscience-based science modules, digital interactive media, and multisensory strategies that are aligned with how the child's brain works. A number of experimental and quasi-experimental studies have confirmed the effectiveness of neuroscience-based AR media in improving learning outcomes and motivation of elementary school students.

The 2025 study and the findings of Cai et al. (2022) show that dynamic visualization and active interaction in AR are able to strengthen the formation of abstract science concepts and increase students' cognitive engagement. AR media designed with visualization, interactivity, and cognitive load in mind has been shown to facilitate memory encoding processes and deeper conceptual understanding. In addition to AR, Brain-Based Learning (BBL) emerged as the dominant and consistently effective approach. R&D research by Sucilestari (2023) and quasi-experimental studies by Oktavianto et al. (2025), Saeed & Kayani (2025), and Lalu et al. (cognitive load is closely related to 2022 motivation) show that BBL is able to improve the understanding of science concepts, science literacy, learning outcomes, and critical thinking skills of elementary school students. The advantage of BBL lies in its ability to optimize the activation of emotions, attention, and memory systems, so that learning becomes more meaningful and lasts longer. Findings from qualitative studies and literature studies (Amelia et al., 2021; ResearchGate, 2021; Rukmini, 2024) strengthens the evidence that neuroscience-based learning is in harmony with the cognitive development stages of elementary school children. This approach emphasizes the importance of learning experiences that are contextual, meaningful, and involve a variety of senses. Neuroscience-based concrete media, such as those developed in the 2025 proceedings research, show that kinesthetic and multisensory approaches are effective in strengthening students' understanding and learning behaviors From a learning design perspective, the results of systematic studies and literature reviews (Intantri et al., 2025; research journal, 2024) reveal that science media innovations—such as digital storytelling, Project-Based Learning (PjBL), and gamification—have a positive impact on students' interest and understanding of concepts.

However, most of these media have not been explicitly designed based on neuroscience principles, so there is still a great opportunity for the development of more neurocognitively integrated media. Theoretically, the findings of Evans et al. (2023) reinforce the conceptual foundation of this approach by showing that student autonomy. Learning designs that reduce cognitive overload and support basic psychological needs (autonomy, competence, and connectedness) will improve intrinsic motivation and learning quality. This is reinforced by research based on Dual Coding Theory (Damayanti & Yuliana, 2023) which shows that visual and verbal combinations—such as songs and pictures—significantly improve vocabulary mastery and information retention, especially in early childhood. Overall, this synthesis shows that

The integration of neuroscience in elementary science learning, both through digital media (AR, interactive multimedia), learning models (BBL, PBL), and cognitive strategies (multisensory, dual coding, cognitive load management), has been proven to be effective in improving the quality of learning. However, there is still a research gap related to the design of neuroscience-based science media that systematically integrates cognitive, affective, and technological principles, thus opening up opportunities for the development of more comprehensive neuroscience-based innovative learning models or media.

SLR Results Based on PICO Components

P (Population / Research Subject)

Based on the results of data extraction, the research population is dominated by elementary school (SD) students. The entire article places elementary school students as the main subject, with a focus on integrated science and science learning. In addition, there is one study involving early childhood, which remains relevant because it emphasizes the working principles of the brain in the early stages of development. The dominance of elementary school subjects shows that the neuroscience approach is considered most crucial in the concrete–operational phase of cognitive development, when students need visual, emotional, and multisensory support to build conceptual understanding.

I (Intervention/Intervention)

The interventions identified in this SLR are diverse, but have a common thread in the form of a neuroscience-based approach, which includes: Neuroscience-based learning media, such as: Augmented Reality (AR) media based on neuroscience principles, interactive media and digital storytelling, concrete media and multisensory kinesthetics; Brain-Based Learning (BBL) learning model, both in the form of: BBL-based science modules, neuroscience-based science and biology learning, multisensory strategies, mnemonics, and cognitive load management Cognitive design approaches, such as: Cognitive load reduction, Application of Dual Coding Theory (visual and verbal combination). These interventions are designed to optimize emotional activation, attention, memory, and learning motivation, which are the main mechanisms of the brain's work in the learning process.

C (Comparison)

Most experimental and quasi-experimental studies compare: Neuroscience-based learning with conventional learning, or Conditions before and after the application of neuroscience interventions. Although not all studies explicitly mention control groups (specifically qualitative studies, PTK, and literature studies), comparative patterns suggest that learning without a neuroscience approach tends to be less than optimal in improving students' motivation, conceptual understanding, and critical thinking. The results of the systematic review also show that many innovative science media have not been fully designed based on neuroscience principles, so their effectiveness has not been maximized.

O (Outcome / Outcome)

The main outcomes obtained consistently from all studies include: Improvement of learning outcomes and conceptual understanding of science including AR media, BBL modules, and neuroscience-based learning proven to improve conceptual achievement and understanding of science concepts of elementary school students; Increased motivation and learning engagement include

Interventions that emphasize visualization, interaction, and multisensory experiences increase students' intrinsic motivation, learning interest, and cognitive engagement; Strengthening critical thinking skills and science literacy includes neuroscience-based learning and BBL has a significant effect on critical thinking skills and improving students' science literacy, both through quasi-experiments and PTK; Improved attention, retention, and long-term memory include Multisensory strategies, dual coding, and cognitive load management proven to be effective in improving memory and learning retention, which are also influenced by biological factors such as emotions, sleep, and nutrition; Optimization of brainwork-based learning design includes Theoretical studies show that learning that reduces cognitive load and supports students' psychological needs (autonomy, competence, connectedness) will improve autonomous motivation and learning quality Overall, the results of SLR based on the PICO framework show that elementary science learning with neuroscience-based interventions, both through AR media, Brain-Based Learning, interactive media, and cognitive strategies, are more effective than conventional learning. This approach not only improves cognitive learning outcomes, but also strengthens the affective and metacognitive aspects of students. However, this SLR also reveals a research gap, namely the limited science media that systematically and explicitly integrates the principles of neuroscience, technology, and cognitive design in one complete learning framework

CONCLUSION

Based on the results of the Systematic Literature Review (SLR) with the PICO approach, it can be concluded that the integration of neuroscience principles in science learning media in elementary schools is effective in improving the quality of learning. Neuroscience-based learning media and models have been proven to be able to increase students' learning motivation, attention, conceptual understanding, and science literacy through a more active, meaningful, and harmonious learning experience with how the brain works.

The results of the study show that various neuroscience-based interventions, such as Augmented Reality (AR), Brain-Based Learning (BBL), interactive media, as well as multisensory strategies and cognitive load management, are more effective than conventional learning. However, there is still a need for the development of neuroscience-based science learning media that is systematically and comprehensively designed so that the integration of cognitive, affective, and technological principles can be optimized to support the strengthening of science literacy of elementary school students.

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