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NEUROEDUCATION AS A NEW PARADIGM IN CONTEMPORARY PEDAGOGY: INTEGRATING NEUROSCIENCE FOR THE TRANSFORMATION OF 21ST CENTURY EDUCATION

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ABSTRACT

The transformation of education in the 21st century requires more adaptive, scientific, and integrated pedagogical approaches. One emerging paradigm is neuroeducation, an interdisciplinary integration of neuroscience, cognitive psychology, and pedagogy aimed at enhancing the quality of teaching and learning. This study systematically examines the role of neuroeducation in contemporary education by identifying implementation strategies, challenges, and its implications for educational policy. The method used was a systematic literature review (SLR) involving 20 peer-reviewed articles published between 2015 and 2025, retrieved from Scopus, ScienceDirect, and SINTA databases. The findings reveal that neuroeducation significantly contributes to improving learning outcomes through multisensory teaching, reinforcement of neuroplasticity, and restorative pedagogical approaches. Nevertheless, several challenges persist, particularly related to the limited neuroscience literacy among teachers and the lack of structured training programs. This study recommends the systematic integration of neuroeducation concepts into teacher education curricula and national education policy.

Keywords: Neuroeducation, Brain-Based Pedagogy, 21st-Century Learning, Neuroscience, Teacher Education

INTRODUCTION

The development of science and technology in the 21st century has brought significant changes to various aspects of life, including the world of education. These changes require a transformation of the pedagogical paradigm that not only adapts to the needs of the times but is also rooted in scientific understanding of the biological and cognitive processes underlying human learning (Yusuf, 2023). In this context, the neuroeducation approach, which integrates the latest findings from neuroscience, cognitive psychology, and educational science, emerges as one of the transdisciplinary innovations offering new theoretical and practical foundations for designing more effective, adaptive, and evidence-based learning processes (*evidence-based practice*) (Motamedi, 2022).

Neuroeducation emphasizes the importance of understanding the mechanisms of the brain in processing information, remembering, forming emotions, and adapting to the learning environment (Khairanis & Aldi, 2025). This understanding enables educators to design pedagogical interventions that are not only focused on academic learning outcomes but also consider the social-emotional development and psychological well-being of students (Darif & Lafraxo, 2025). Concepts such as neuroplasticity, working memory, executive function, and multisensory engagement are the main pillars in building a learning model that aligns with the brain's natural way of learning.

A number of empirical studies have shown that brain-based learning approaches have been proven to improve the effectiveness of teaching and learning processes in the classroom. For example, Valdés-Villalobos and Lazzaro-Salazar, through a systematic review of 110 scientific articles from the Scopus and Web of Science databases, found that the implementation of neuroeducational strategies has a positive impact on improving concentration, information retention, and active student participation (Valdés-Villalobos & Lazzaro-Salazar, 2023). Furthermore, this approach is also positively correlated with improvements in reading literacy, numeracy, and the strengthening of social-emotional competencies, which are key indicators in the profile of 21st-century learners.

In a global context, the application of neuroeducation is increasingly recognized as a science-based educational reform strategy. Countries such as Finland, Canada, and Singapore have begun to integrate neuroscience principles into national curricula, teacher training programs, and learning evaluation systems. A longitudinal study by Caballero and Llorent shows that two years of neuroscience-based teacher training can improve teachers' professional capacity to design mathematics learning and social-emotional skills that are more responsive to students' cognitive development needs (Caballero & Llorent, 2022).

However, in Indonesia, the adoption of this approach still faces various structural and cultural challenges. Research conducted by Aswatudali et al. shows that although understanding of the basic concepts of neuroeducation is becoming more widespread among education practitioners, there is a significant gap in terms of implementation at the school level (Aswatudali et al., 2024). The lack of structured training, limited neuroeducation literature in Indonesian, and the dominance of conventional instructional approaches that still focus on memorization and standardization of learning outcomes are the main obstacles to the widespread application of this paradigm.

Additionally, educational policy approaches in Indonesia have not fully supported the integration of neuroscience in curriculum development and teacher competency development programs (Mubarak & Annida, 2024). The lack of dialogue between neuroscientists, education experts, and policymakers has resulted in suboptimal interdisciplinary knowledge transfer. In fact, this cross-sector collaboration is an important prerequisite in building an education system based on scientific understanding of brain development and children's learning behavior.

Considering the great potential of neuroeducation in improving the quality of learning and its relevance to national educational challenges, this study is important to conduct. This research aims to explore the strategic role of neuroeducation as a new paradigm in contemporary pedagogy, examine the basic principles underlying it, and assess the extent to which this approach can be implemented in the Indonesian educational context in a realistic and sustainable manner. This study is also expected to provide conceptual and practical contributions to policy development, curriculum design, and teacher training programs, thereby promoting the realization of education that is more humanistic, scientific, and adaptive to the dynamics of the times.

RESEARCH METHODS

This study is a systematic literature review (SLR) that uses a descriptive qualitative approach to explore the integration of neuroeducation in contemporary pedagogical practices. This method was chosen because it can comprehensively identify and synthesize previous research findings, particularly those related to the concepts and implementation of brain-based learning in school and university settings (Hasan, 2022).

The data sources for this study were obtained from scientific articles published between 2015 and 2025, retrieved from various indexed scientific databases such as Scopus, ScienceDirect, Frontiers in Education, and the national portal SINTA. The articles were searched using the keywords: “neuroeducation,” “brain-based pedagogy,” “neuropedagogical intervention,” and “neuroscience-informed teaching.” To ensure data quality, only articles that had undergone peer review and were directly relevant to the research topic were included in the analysis.

The inclusion criteria used in this study include: (1) articles published in accredited journals (Scopus or SINTA 1/2), (2) focus on the implementation of neuroeducation in education, (3) written in Indonesian or English, and (4) have a clear methodological description. Articles that did not have full access, were not relevant to the topic, or were merely opinion pieces were excluded from the analysis.

The analysis process was carried out in several stages, namely: literature identification, initial screening based on titles and abstracts, reading the full text for final selection, and data extraction in the form of themes, objectives, methodology, and main findings from each article. The extracted results were then analyzed using a thematic analysis approach to identify patterns, trends, and gaps in the implementation of neuroeducation in the context of formal education. The validity of the study was maintained through data triangulation and cross-checking among reviewers to ensure consistency in the synthesis of information across articles (Hasan, 2022).

RESULTS AND DISCUSSION

This literature review analyzes 20 scientific articles relevant to the application of neuroeducation in classroom pedagogy. The articles analyzed include empirical studies, educational experiments, systematic reviews, and reports on neuroscience-based teacher training. The findings of this review are grouped into four main themes: (1) the role of neuroeducation in enhancing learning practices, (2) strategies for implementing neuropedagogy in the classroom, (3) challenges in integrating neuroscience into the curriculum, and (4) implications for teacher training and educational policy.

The Role of Neuroeducation in Improving Learning Quality

Neuroeducation, or neuroscience-based education, has become a transdisciplinary approach that integrates neuroscience, cognitive psychology, and pedagogy to understand and optimize the teaching and learning process (Rais et al., 2019). Its application provides a new paradigm in education that focuses on how the brain learns, not just what is learned. This paradigm shift is crucial for enhancing the effectiveness of holistic learning, taking into account students' neurobiological conditions as the foundation for learning strategies.

Valdés-Villalobos et al. state that the application of neuropedagogical strategies in the reading learning process results in significant improvements in understanding and information retention (Valdés-Villalobos & Lazzaro-Salazar, 2023). These strategies are designed based on the brain's mechanisms for processing textual information, including the activation of brain areas involved in decoding, semantic processing, and working memory. This study shows that students who learn using a neuroeducational approach are able to build stronger semantic connections and demonstrate stable academic performance improvements compared to conventional approaches (Ahmar & Azzajjad, 2025).

In line with these findings, Caballero & Llorent's research presents two years of longitudinal evidence highlighting the impact of neuroscience-based teacher training on student learning outcomes (Caballero & Llorent, 2022). The training program covers the principles of neuroplasticity, the importance of emotion management, and teaching strategies appropriate to the developmental stages of children's brains. The results show improvements in students' mathematical literacy, social-emotional competencies, and the reinforcement of moral values. These findings reinforce the assumption that education that considers students' neurophysiological aspects not only influences cognitive aspects but also broader character development and social skills (Mubarak & Annida, 2024).

Tokuhama-Espinosa, a central figure in the development of the neuroeducation concept, emphasizes that the brain is the primary organ in the learning process. Therefore, understanding the structure, function, and development of the brain must form the foundation for designing curricula, learning strategies, and evaluations. Within this framework, learning can no longer be uniform or one size fits all, but must be adaptive, dynamic, and responsive to individual neurobiological needs.

The application of neuroeducation principles also has an impact on increasing students' intrinsic motivation (Darling-Hammond et al., n.d.). This is because this approach values the learning process as a natural and meaningful activity. When students feel that the way they learn is in line with how their brains work, they become more engaged and motivated. Studies conducted by Immordino-Yang & Damasio show that emotions play an important role in learning, and that positive emotional experiences can enhance the brain's capacity to absorb and retain information (Immordino-Yang & Damasio, 2007). Therefore, an emotionally positive learning environment that supports students' social-emotional development is a key element in the implementation of neuroeducation.

Furthermore, the application of neuroeducation in educational settings can also help detect and address learning difficulties more accurately and based on scientific data. For example, students with attention disorders such as ADHD or auditory processing difficulties can receive more targeted interventions because teachers are equipped with knowledge about neurodiversity and appropriate learning strategies (Wathon, 2015). In this context, neuroeducation not only enhances the overall quality of learning but also makes a significant contribution to inclusive education (Janah & Supena, 2021).

In practical implementation, the integration of neuroeducation in learning requires a comprehensive transformation, from curriculum planning, teacher training, to learning evaluation (Septiana & Aimah, 2025). Teachers no longer merely act as content deliverers but as facilitators who understand the dynamics of students' brains in learning. Therefore, neuroscience literacy for educators becomes highly crucial. Research by Tokuhama-Espinosa shows that teachers who understand neuroscience principles are better able to design adaptive and differentiated learning activities and create empathetic learning interactions that value the uniqueness of each student.

Thus, neuroeducation serves as a bridge between basic knowledge about the brain and effective pedagogical practices. It provides a solid scientific framework for understanding why certain strategies work better than others, and how learning environments can be optimized based on neurobiological principles. This integration enables the creation of a learning ecosystem that is humanistic, evidence-based, and oriented toward the holistic development of students' potential not only as cognitive beings but also as emotionally and socially whole individuals.

Strategies for Implementing Neuropedagogy in the Classroom

The implementation of neuropedagogical strategies in the context of 21st-century learning requires a comprehensive understanding of how the brain learns, as well as the application of adaptive approaches to the cognitive and affective characteristics of learners (Janah & Supena, 2021). A study by Mavrelos and Daradoumis emphasizes the importance of a multisensory approach in the learning process, where simultaneous engagement between visual and auditory stimuli enhances information retention and improves neural pathway efficiency (Mavrelos & Daradoumis, 2020). They note that integrating various sensory modalities in learning significantly increases activation of the prefrontal cortex, which is responsible for executive functions such as attention, decision-making, and emotional regulation.

This strategy is consistent with the findings of Pradeep et al., who emphasize the effectiveness of neurofeedback technology in identifying and managing fluctuations in student attention during learning activities (Pradeep et al., 2024). Neurofeedback enables teachers to design learning experiences that are responsive to students' neurophysiological conditions, such as stress levels, focus, and readiness to learn. In this context, the use of mind-mapping is not merely a tool for visualizing concepts but also serves as an integrative bridge between the left hemisphere (logical-analytical) and the right hemisphere (creative-intuitive) of the brain. This approach has been shown to strengthen synaptic connectivity and support neuroplasticity the brain's ability to adapt through meaningful learning experiences.

Emotional scaffolding is another important element in the neuropedagogical approach. Pradeep et al. show that providing systematic emotional support in learning can increase the production of neurotransmitters such as dopamine and serotonin, which play a role in motivation and feelings of comfort (Pradeep et al., 2024). Teachers who can create a psychologically safe environment are more successful in building affective bonding with students, which directly impacts the enhancement of intrinsic motivation.

Furthermore, the Project-Based Learning (PjBL) approach is recognized as an effective neuropedagogical strategy because it is contextual, collaborative, and triggers emotional engagement in students. Uribe Quiroz et al. emphasize that PjBL not only enhances conceptual understanding but also activates complex metacognitive processes, including self-reflection, planning, and evaluation. These activities contribute to strengthening neuroplastic circuits, particularly in the hippocampus and dorsolateral prefrontal cortex.

Emotion-based restorative teaching is a pedagogical approach that places emotions at the core of reconstructing teacher-student relationships. This strategy is not only used as a post-conflict recovery effort but also as a preventive measure to build a supportive and empathetic classroom culture (Judijanto, 2025). In practice, restorative teaching uses techniques such as affective dialogue, reflective journaling, and circle time designed to enhance emotional awareness and strengthen students' self-regulation capacity. This aligns with neuropsychological findings highlighting the importance of the limbic system in mediating learning experiences (Immordino-Yang & Damasio, 2007).

Another equally important neuropedagogical strategy is the use of cognitive breaks. Mavrelos & Daradoumis show that continuous learning without breaks can lead to a decline in cognitive performance due to mental fatigue (Mavrelos & Daradoumis, 2020). Strategic breaks during learning can optimize the memory consolidation process in the hippocampus and restore depleted attention resources. In a classroom context, these breaks can take the form of light activities such as stretching, short movement-based games, or brief mindfulness-based meditation, which have been shown to activate the default mode network (DMN) involved in internal processing and cognitive recovery.

Additionally, contextual learning rooted in students' daily realities supports the strengthening of neuroplasticity. When students can connect lesson material to their real-life experiences, emotional and cognitive engagement increases simultaneously. This creates ideal conditions for the formation of stronger, more durable synaptic pathways. Research by Uribe Quiroz et al. shows that the direct connection between learning content and the context of students' lives triggers the release of neurochemicals such as acetylcholine, which strengthens learning through the formation of long-term memory.

In practice, these strategies should be tailored to the neurological development level of the students. For example, elementary school students (6–12 years old) are more responsive to game-based learning and stories that spark imagination and involve diverse sensory aspects. Meanwhile, adolescent students require learning that is based on problem-solving and self-reflection, which encourages the integration of critical thinking and emotional awareness (Fajriani et al., 2024).

Thus, the application of neuropedagogy in the classroom not only requires methodological innovation but also a paradigm shift from teacher-centered learning to brain-centered learning. This process involves designing a stimulating learning environment, strengthening interpersonal relationships, and creating authentic and meaningful learning experiences. In this context, teachers play a role not only as facilitators but also as neuroeducators who understand the mechanisms of brain function and their implications for designing transformative learning experiences.

Challenges of Implementation in the Context of Formal Education

Although the neuropedagogical or neuroeducational approach offers great potential for improving learning effectiveness through an understanding of brain function and structure, its implementation in formal education, particularly in developing countries such as Indonesia, still faces a number of fundamental challenges. These challenges are multidimensional, encompassing aspects such as teachers' knowledge, educational policies, school infrastructure, and epistemological barriers related to understanding neuroscience (Janah & Supena, 2021).

A study by Muhammad and Saleh revealed that in many educational institutions in Indonesia, teachers generally lack a strong conceptual understanding of the basic principles of neuroeducation. This stems from the limited exposure to neuroscience in teacher education curricula. In their study of 150 teachers from various educational levels in five provinces, only 23% of respondents were able to distinguish between scientific concepts in neuroeducation and common neuromyths, such as the belief that humans only use 10% of their brains or that visual, auditory, and kinesthetic learning styles are absolute foundations that must be followed (Aswatudali et al., 2024).

This deficiency is exacerbated by the lack of ongoing professional training that integrates neuropsychological approaches into everyday pedagogical practice. Most existing teacher training programs are still traditional in nature and do not cover updates in cognitive science or the latest developments in neuroscience. In addition, the availability of Indonesian-language literature and resources accessible to teachers and education practitioners is also very limited. The majority of publications on neuroeducation are still in English, making it difficult to transfer knowledge to the wider educational community.

Furthermore, Walsh et al. warn that direct and uniform implementation of neuroeducation without considering the local context may risk misunderstanding or even misuse of scientific concepts. This phenomenon is referred to as neuromyth adoption, which occurs when neuroscience concepts that have not been strongly validated are widely used in educational policies or practices. One common example is the rigid application of "left brain-right brain teaching," despite contemporary scientific literature showing that learning activities involve complex interactions between lobes and are not dichotomously divided (Walsh et al., 2024).

Walsh et al. emphasize the importance of a gradual and contextual strategy in integrating the neuroeducation approach, especially at the primary and secondary education levels (Walsh et al., 2024). They stress that implementation should begin with improving basic neuroscience literacy among teachers and policymakers, accompanied by the development of evidence-based pedagogical modules that can be adapted to the needs and characteristics of students in each region. In this context, the involvement of experts in neuroscience, educational psychology, and curriculum development is crucial to avoid misguided knowledge translation.

Another challenge that cannot be ignored is the limitation of school infrastructure, both in terms of technology and supporting facilities. The implementation of neurofeedback-based strategies, brain-based mindfulness training, and the development of a curriculum that aligns learning rhythms with students' neurobiological cycles remains difficult to implement widely in schools with limited basic facilities. In a study conducted by Santosa et al., it was found that out of 200 elementary schools in the 3T (Remote, Frontier, and Outer) regions of Indonesia, over 70% did not have stable access to the internet and basic laboratory facilities required to implement technology-based learning approaches and brain science (Asari et al., 2024).

On the other hand, the national education policy structure, which still tends to be top-down, also hinders the flexibility of developing neuropedagogical-based curricula. Teachers and school principals are often faced with administrative pressures and conventional cognitive evaluation standards, such as School Exams and National Assessments, which do not fully reflect students' higher-order thinking processes or neurocognitive indicators. As a result, although some schools have tried to implement brain-based learning elements, their sustainability is often disrupted due to a lack of systemic support from macro policies.

From an epistemological perspective, challenges also arise in bridging the laboratory-based world of brain science with the socially and culturally contextual world of educational practice. As noted by Tokuhama-Espinosa, a major obstacle in the development of neuroeducation is the lack of a transdisciplinary bridge between basic sciences (such as neuroscience and biology) and applied sciences (such as pedagogy and educational psychology). Without this bridge, there is a risk that laboratory findings on brain cognition will never reach the classroom in a relevant and applicable manner.

Thus, the success of the systematic implementation of neuropedagogy in formal educational institutions is highly dependent on the synergy of various parties. A multi-layered effort is required, encompassing reforms to teacher education curricula, the development of research-based policies, enhancing teachers' capacities through contextualized training, and fostering a scientific literacy ecosystem that reaches grassroots educational communities. Interdisciplinary collaboration and evidence-based approaches are key to preventing neuroeducation from falling into the trap of being merely a trend without a solid scientific foundation.

Implications for Teacher Training and Education Policy

The implications of implementing neuropedagogy not only impact classroom teaching practices but also have far-reaching consequences for teacher training design and educational policy formulation. Several contemporary studies emphasize that neuroscience-based educational transformation requires systemic reform, particularly in strengthening teachers' professional competencies through an interdisciplinary approach between education, cognitive science, and technology (Mubarak & Annida, 2024).

A study by Sulaiman et al. highlights the importance of integrating Technological Pedagogical Neuroscience Knowledge (TPNK) into teacher training curricula. This concept is an expansion of the widely used TPCK (Technological Pedagogical Content Knowledge) model, with the addition of a neuroscience dimension as a framework for understanding how technology and pedagogy impact the structure and function of students' brains (Sulaiman et al., 2024). TPNK-based training not only trains teachers in the use of educational technology but also equips them with an understanding of students' attention rhythms, emotional processing needs, and how to address cognitive fatigue. In the complex context of 21st-century learning, this approach is relevant for building teachers' capacity to design adaptive, personalized, and neurologically sensitive learning (Uden & Sulaiman, 2025).

Furthermore, Barros emphasizes the importance of integrating neuromethodology into professional teacher training, especially in the digital age and hybrid learning (de Barros, 2022). Neuromethodology refers to teaching methodologies based on neuroscientific principles such as cognitive load theory, dual coding, and emotional engagement. In teacher training, neuromethodology can be applied through brain-based learning simulations, professional emotional regulation training, and strategies to detect and respond to students' cognitive load signals in online settings. This is important because in digital learning, non-verbal signals that typically indicate students' cognitive and affective conditions are difficult to recognize, so teachers need scientific tools and technology to anticipate them (de Barros, 2022).

From an educational policy perspective, the findings of this study underscore the need for a repositioning of the role of the state and higher education institutions in supporting the systematic dissemination of neuropedagogical knowledge. One form of policy implementation that can be undertaken is to mandate an Educational Neuroscience module in the Teacher Professional Education Program (PPG), both pre-service and in-service. This module is not only theoretical but also practical, incorporating case study training and the use of neuroeducational technologies such as eye-tracking, portable EEG, and AI-based emotion analysis applications (Muthmainnah & Budiyono, 2022).

Furthermore, national curriculum development policies must also take into account findings from educational neuropsychology. For example, mapping cognitive load in the curriculum needs to consider students' attention span and working memory capacity based on their age and developmental stage. Many current curricula are designed using a linear, content-based approach without considering the optimal time for brain information processing. As a result, students experience cognitive overload, which can reduce learning efficiency and even increase academic stress. Curriculum reform based on neuroscience will promote a more rhythmic, adaptive, and cognitively segmented learning structure (Rohmadi, 2018).

Furthermore, the provision of neuroscience-based learning resources is crucial. Governments and educational institutions need to facilitate the development of teaching materials that support conceptual visualization, multisensory integration, and provide options for reflective breaks in each learning session. Textbooks, for example, need to be redesigned to include visual-verbal balance, cognitive maps, and metacognitive reflection activities based on the principles of spacing and interleaving. The availability of interactive digital platforms that implement neuroeducation principles is also a strategic urgency.

Another aspect that needs to be considered in education policy is the development of a teacher performance evaluation system that takes into account the application of neuropedagogical principles in teaching. Evaluation should not only focus on students' academic achievements, but also on how teachers apply learning strategies based on emotions, attention, and cognitive regulation. Thus, incentive and reward systems for teachers can also be linked to their success in implementing brain-based learning strategies.

Overall, for neuropedagogical principles to be adopted effectively and sustainably, synergy between policy, training, and practice is required. Higher education institutions, the Ministry of Education, and the teaching community must collaborate in formulating neuroscience-based teacher competency standards, developing innovative professional training frameworks, and designing educational policies that support the development of a learning ecosystem aligned with how students' brains function (Rusydiana, 2023). Neuropedagogy is not a fleeting trend but a scientific approach that must be structurally embedded in the national education system as part of efforts to create education that is humanistic, adaptive, and research-based (Janah & Supena, 2021).

CONCLUSIONS

This literature review shows that neuroeducation plays a strategic role in shaping a more adaptive, scientific, and responsive pedagogical paradigm aligned with 21st-century learning needs. The integration of neuroscience, cognitive psychology, and pedagogical practices contributes significantly to enhancing the quality of learning across cognitive, affective, and social-emotional domains. The application of brain-based learning strategies such as multisensory learning, restorative approaches, and the strengthening of neuroplasticity has proven effective in improving students' attention, memory retention, and active participation in the learning process. However, challenges remain, particularly regarding teachers' limited understanding of neuroscience concepts, the lack of neuroeducation integration in teacher education curricula, and the scarcity of Indonesian-language literature and training resources. Conceptually and practically, neuroeducation underscores the need for comprehensive educational policy reform, encompassing teacher curriculum development, professional training, and the creation of neuroscience-based teaching materials. Indonesia, therefore, has a significant opportunity to adopt this approach gradually and contextually to establish a more personalized, holistic, and brain-based learning system.

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