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Bridging Educational Neuroscience and Instructional Practice in Primary Schools through Teachers' Neuropedagogic Understanding

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***Abstract**: The development of educational neuroscience has provided an increasingly comprehensive understanding of learning as the result of interactions among biological, emotional, social, and environmental factors. Nevertheless, the application of neuroscientific findings in instructional practices at the elementary school level continues to face various challenges. This study aims to bridge educational neuroscience and classroom practice by analyzing elementary school teachers' understanding and implementation of neuropedagogical principles. A mixed methods approach with an embedded design was employed, integrating quantitative and qualitative data. Quantitative data were collected through a Likert-scale questionnaire to identify trends in brain-based instructional practices, while qualitative data were obtained through semi-structured interviews to explore teachers' pedagogical experiences and reflections. The findings indicate that teachers' instructional practices are largely aligned with principles of educational neuroscience, particularly in the management of emotional readiness, multisensory learning, and attention regulation. These results underscore that the primary challenge in implementing neuropedagogy lies not in teaching practices themselves, but in teachers' literacy in educational neuroscience. Strengthening teachers' conceptual understanding has a recognized potential to optimize existing practices, making them more systematic, reflective, and sustainable in supporting the cognitive, emotional, and social development of elementary school students.*

***Keywords:** Brain Based Learning, Educational Neuroscience,Elementary Education.*

INTRODUCTION

The development of neuroscience in the last two decades has made significant contributions to the understanding of how humans learn, process information, regulate emotions, and build memory. Neuroscience views the learning process not solely as a cognitive activity, but as the result of complex interactions between biological, emotional, social, and environmental aspects that affect each other (Immordino-yang & Damasio, 2007; Thompson, 2014). In the context of education, the understanding of how the brain works encourages the birth of the neuropedagogic approach, which is an interdisciplinary study that integrates neuroscience, educational psychology, and pedagogy to design learning that is in harmony with the natural mechanisms of the human brain. Neuropedagogic emphasizes that learning will be more effective when it is adapted to the way the brain receives stimuli, processes information, regulates emotions, and builds short-term and long-term memory connections (Torop, 2025). Conceptually, the application of neuropedagogic in learning cannot be separated from the understanding of neuroanatomy and neurophysiology of the brain. Neuroanatomy deals with the structure of the brain and nervous system, while neurophysiology focuses on the function and mechanism of action of parts of the brain in responding to stimuli and producing behaviors (Dekker et al, 2012). Neural science is etymologically rooted in the study of the nervous system, especially neurons as the basic unit of information processing in the brain (Diamond, 2013).

Neuroscience is a field of science that scientifically studies the nervous system, including the structure, function, development, and dynamics of neural activity that underlie human behavior. As a fast-growing branch of biological science, neuroscience is multidisciplinary because it involves psychology (cognitive neuroscience and neuropsychology), physiology, biochemistry, pharmacology, informatics, statistics, and medical science. Within this framework, psychology is often positioned as a subfield of neuroscience because it studies mental processes and human behavior that can be scientifically modeled and have a direct relationship with neural activity. Neuroscience aims to explain human behavior through an understanding of the biological activities that occur in the brain (Diamond, 2013). Neuroscience shows that cognitive, emotional, motivational, and learning processes are inseparable from the work of the nervous system (Caine, 2005; Jensen & McConchie, 2020). The brain not only functions as a stimulus receiving center, but also as a response regulator, meaning-former, and behavioral controller through complex interactions between parts of the brain, such as the prefrontal cortex, limbic system, and hippocampus. This understanding is an important foundation for the application of neuroscience in education, because the learning process is essentially the result of neural activity that is influenced by experiences, emotions, and learning environments (Howard, 2014).

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Neuropedagogic approaches have strong relevance in the context of primary school education, as this level serves as a foundational stage for students' cognitive, social-emotional, moral, and character development. At the elementary level, children are in the concrete operational stage, where learning depends heavily on direct experiences, multisensory stimulation, and social interaction (Piaget, 1970; Gruart et al, 2023). Learning activities that are not aligned with these developmental characteristics risk reducing the meaningfulness and effectiveness of the learning process. From a neurobiological perspective, the brains of elementary school-age children are still undergoing rapid development, particularly in areas related to executive functions, emotional regulation, attention, and memory (Morales et al., 2024). Neuroscience research shows that learning effectiveness is closely linked to how information is processed through neural networks, which are strongly influenced by emotional safety, motivation, and meaningful engagement (Harricharan et al., 2021). Therefore, instructional practices that neglect students' brain development stages may hinder optimal learning outcomes (Hasan & Kumar, 2024).

Neuropedagogy bridges neuroscience findings with classroom practices by emphasizing balanced stimulation between cognitive, emotional, social, and physical aspects of learning. In elementary education, this approach highlights the critical role of teachers in designing learning environments that support brain-based learning principles, such as active engagement, emotional security, and experiential learning (Alkhasawneh & Sharif, 2025). Teachers are not only transmitters of knowledge but also facilitators who shape learning experiences in ways that align with students' neurological and developmental needs. However, despite the growing recognition of neuroscience-based learning, the integration of neuropedagogic principles into elementary classroom practices remains limited and uneven. This condition raises questions about how neuropedagogic approaches are understood and implemented by teachers, as well as their potential contribution to improving learning quality in primary education. Therefore, this study focuses on examining the application of neuropedagogic principles in elementary school learning and the role of teachers in implementing brain-based instructional practices.

Significant gaps between the development of neuroscience theory and the reality of instructional practice in elementary school classrooms. Although scientific evidence suggests that the quality of learning stimuli is highly determinative of cognitive success, many teachers are still stuck in conventional methods that ignore the neurophysiological aspects of students. The main problem arises when the cutting-edge findings of neuroscience only stop as academic literature without being able to be operationalized by educators. Teachers' lack of understanding of how positive emotions and multisensory experiences affect long-term memory formation causes the learning process in elementary school to often be rigid and less supportive of optimal brain development (Sambas, 2025; Wardoyo & Utanto, 2025).

This study aims to analyze the urgency of strengthening teachers' neuropedagogic understanding. This study maps the extent to which the principles of brain work have been implemented by teachers in elementary schools through the distribution of questionnaires and delves into the perspective and practical experience of teachers in integrating these brain-friendly strategies through in-depth interviews. The *novelty* of this research lies in the synthesis of a neuropedagogic framework based on empirical data in the field, which not only emphasizes the purely cognitive aspect, but also proves the importance of emotional balance and varied neural stimulation as the main pillars of learning. By bridging field data and neuroscience theories, this article offers a concrete solution model for teachers to design learning experiences that are more adaptive and aligned with how students' brains work.

METHOD

This study employed a descriptive–exploratory research design using an embedded mixed methods approach. The study aimed to obtain a comprehensive understanding of elementary school teachers’ knowledge and implementation of neuropedagogic principles in classroom learning practices. In the embedded mixed methods design, qualitative methods served as the primary approach, while quantitative methods functioned as supporting data. The qualitative approach was prioritized to explore teachers’ experiences, instructional practices, and challenges in implementing neuropedagogic principles. Quantitative data were used to complement and strengthen the qualitative findings by describing the general level and tendencies of teachers' neuropedagogic understanding. The research was conducted in sequential stages. In the first stage, quantitative data were collected using a Likert-scale questionnaire (1–5) completed by elementary school teachers at one public elementary school in Bogor (initial "G"). The questionnaire measured teachers' understanding of neuropedagogic concepts, perceptions of neuroscience principles in learning, and tendencies to apply brain-based learning strategies in classroom practice. The instrument was developed based on key indicators of neuropedagogic understanding, including knowledge of how the brain functions in learning, management of students' attention and emotions, and the implementation of learning strategies aligned with brain-based learning principles.

In the second stage, qualitative data were collected through semi-structured interviews with two elementary school teachers from the same school. The interview participants were selected using purposive sampling, based on teaching experience and active involvement in classroom instruction. The interviews explored teachers' experiences in applying neuropedagogic principles, challenges encountered during instruction, and strategies used to adapt learning activities to students' cognitive and emotional characteristics. This study focused on one main variable, namely teachers' understanding and implementation of neuropedagogic principles. Accordingly, the study was descriptive and exploratory in nature and did not aim to examine causal relationships between variables. In the final stage, quantitative and qualitative data were integrated at the interpretation stage. Questionnaire results were used to support and clarify the interview findings, enabling a comprehensive understanding of how teachers' neuropedagogic understanding bridges educational neuroscience and classroom learning practices in elementary education.

RESULT AND DISCUSSION

Neuropedagogy is an interdisciplinary study that integrates three fields of science that have developed before, namely psychology, neuroscience, and education (Chojak, 2018). As a branch of social science, neuropedagogy focuses on understanding the development and changes in educational mechanisms that take place throughout human life. This approach places the learning

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process as a phenomenon that is not only pedagogical in nature, but also closely related to the biological and psychological aspects of the learner. Conceptually, neuropedagogy aims to improve the quality of learning through the use of scientific findings regarding how students' brains, memory, language, emotions, and cognitive structure work. By understanding how the brain learns and develops, educators can design learning strategies that are more effective, adaptive, and appropriate to the student's developmental characteristics. Therefore, the scope of neuropedagogy studies includes several main tasks, namely collecting information about neurobiological conditions in the context of education, analyzing the relationships and dynamics that occur in the reality of learning, and disseminating this knowledge as a basis for transforming educational practices to be more in harmony with the way the brain works. The following is a diagram of the neuropedagogy study.

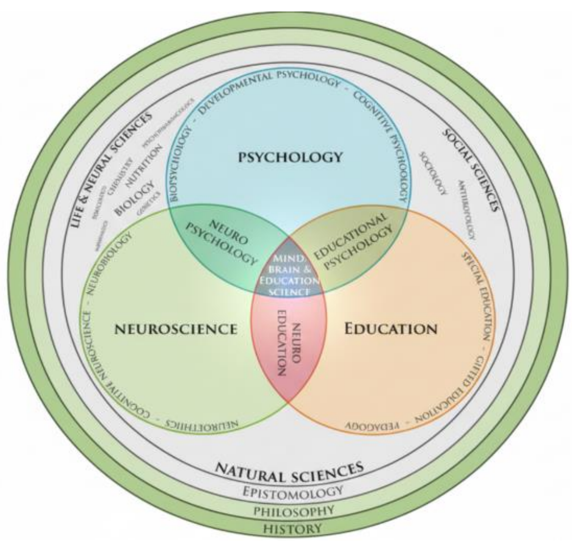

Figure 1. Interdisciplinary diagram of neuropedagogical studies.
Chojak (2018)

The development of a child's brain and emotions suggests that the early years of life play a very important role in determining the quality of an individual's growth, development, and future success (Attanasio et al, 2022). Cognitive and emotional development are inseparable from the

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educational process. Therefore, the integration of neuroscience research results and children's emotional development into pedagogical studies is an urgent need. This condition encourages the emergence of a scientific dialogue between educators and neurologists with the aim of exploring new approaches in pedagogy that are more scientifically evidence-based and oriented towards the development of students' brains (Jolles et al, 2021).

The results of this study indicate that the learning practices applied by primary school teachers are basically aligned with the principles of educational neuroscience, although the conceptual understanding of neuropedagogic is still at the surface level. The integration between quantitative and qualitative data shows that there is a gap between theoretical literacy and practical competence. Teachers show strong ability to manage aspects of emotional readiness, use a multisensory approach, and strengthen students' attention during learning, but these practices are not fully grounded in a systematic theoretical understanding of how the brain works in the learning process. This condition suggests that the application of neuropedagogic principles in the classroom takes place intuitively, not as a result of deep conceptual mastery.

Emotional Readiness as the Foundation of Brain-Based Learning

Quantitative findings show that the dimension of emotional readiness is in the very high category with a percentage of 84.6%. This achievement indicates that teachers consistently create a safe, positive, and psychologically supportive learning environment. The results of the interviews reinforced these findings through conscious learning practices involving ice breaking, light activities, and affective strategies to lower students' emotional tension before entering core learning. This approach shows that teachers understand the importance of students' emotional states as a prerequisite for engagement and readiness for learning.

In the perspective of educational neuroscience, the practice has significant neurobiological implications. Effective emotion regulation plays a role in suppressing the activity of the amygdala, which is the part of the brain that functions to process threat and stress responses. When amygdala activation can be minimized, the prefrontal cortex has the opportunity to function optimally in managing executive functions, such as attention, decision-making, self-control, and problemsolving. Thus, the creation of a safe and enjoyable learning environment is not just a pedagogical strategy, but a neurocognitive intervention that facilitates brain work at a higher level.

These findings are in line with affective neuroscience theories that assert that emotions have a central role in the learning process. Positive emotions not only increase student motivation and engagement, but also affect the process of encoding and storing information in long-term memory. Learning that takes place in emotionally stable and supportive conditions allows information to be processed in a more in-depth and meaningful way (Liu, 2022). Therefore, emotional readiness can be understood as the biological foundation of brain-based learning that determines the effectiveness of subsequent cognitive and academic strategies.

Thus, the results of this study confirm that the management of emotional readiness is a key component in bridging educational neuroscience and learning practices in elementary schools. Although teachers have not fully mastered the concept of neuropedagogic theoretically, the practice applied has reflected the core principles of educational neuroscience. These findings reinforce the urgency of strengthening neuroscience literacy for teachers so that learning practices that have run intuitively can be developed into a more systematic, reflective, and scientific evidence-based approach.

Multisensory and Contextual Learning as a Cognitive Bridge

The multisensory and contextual dimensions showed high achievement with a percentage of 76.9%, which indicates that learning practices in the classroom have actively involved various sensory modalities. Interview data revealed that teachers used various strategies such as the use of learning videos, realia media, simulations, simple experiments, and movement activities to help students understand abstract concepts. This approach allows students to gain a more concrete and meaningful learning experience, so that the process of understanding takes place not only verbally, but also through direct engagement with the learning environment.

Viewed from a neurocognitive perspective, multisensory learning strengthens the formation and connectivity of neural networks because information is processed simultaneously through visual, auditory, kinesthetic, and tactile pathways. The activation of these sensory pathways expands the areas of the brain involved in the learning process, thereby increasing the depth of information processing and strengthening the process *Encoding* into long-term memory. Principle *embodied cognition* explains that learning becomes more effective when the involvement of the brain, body, and environment occurs in an integrated manner (Allen & Friston, 2018). In this context, contextual learning practices that relate material to students' real experiences serve as biological bridges that connect stimuli from the external environment with the sensory cortex and associative cortex, thereby enriching the mental representations that are formed.

The findings of the study also show that teachers often interpret the multisensory approach as an attempt to adapt learning to students' learning styles. However, based on educational neuroscience studies, the effectiveness of multisensory learning does not solely lie in adjusting to individual learning preferences, but in expanding neural activation that allows information to be processed in a more in-depth and integrated manner. Thus, the learning practices that have been carried out are actually in line with the scientific principles of neuroscience, although the theoretical meaning still needs to be strengthened so that the implementation of learning can take place more consciously, systematically, and based on scientific evidence.

Attention, Brain Breaks, and Learning Rhythm Regulation

The dimensions of attention and focus obtained high scores in the range of 67.3%–69.2%, which indicates that teachers are quite effective in maintaining students' attention during the learning process. The qualitative findings show the use of various strategies, such as focus tapping, singing, short games, segmentation of material in short durations, and variations of learning activities. These strategies reflect a practical understanding that the attention span of elementary school students is limited and fluctuating, requiring adaptive and dynamic management of learning rhythms.

From a neuroscience point of view, the practice is closely related to activation *Reticular Activating System* (RAS), which is the nervous system that plays a role in regulating the level of alertness, readiness to learn, and filtering stimuli that enter the brain (Hall et al, 2023). Application *Brain*

Breaks which involves physical movements, sound stimulation, and activities that evoke positive emotions function to reset the level of brain activation when attention begins to decline. This activity helps reduce cognitive fatigue and restore the brain's readiness to receive new information, so that the learning process can continue optimally.

In addition to serving as a focus recovery strategy, the use of games in learning also has broader neurocognitive impacts. Games that involve selective attention, turn taking and quick responses contribute to the development of *executive functions*, such as *working memory*, *cognitive flexibility*, and *inhibitory control*. This activation of executive functions is directly related to the role of the prefrontal cortex in attention management and decision-making. Thus, seemingly simple strategies in classroom practice actually have a significant contribution to students' cognitive development in the long term.

Overall, these findings suggest that teachers have applied attention management principles that are aligned with how the brain works, although they have not been fully realized within the framework of educational neuroscience. The use of a variety of activities, *brain breaks*, games, and learning duration settings reflect a learning approach that is responsive to the neurobiological needs of students. This confirms that attention is the main foundation of meaningful learning and needs to be managed consciously through a flexible, varied, and balance-oriented learning design between cognitive stimulation and emotional regulation.

Neuropedagogic Literacy

The synthesis between qualitative and quantitative data reveals a significant pedagogical paradox, namely the limitations of teachers' neuropedagogic literacy at the conceptual level, but accompanied by a high level of alignment of learning practices with the principles of educational neuroscience. This condition reflects the phenomenon of *unconscious competence*, in which learning practices that are in harmony with the way the brain works have been applied intuitively without being accompanied by an explicit theoretical understanding. Teachers have been able to manage students' emotional readiness, attention, and multisensory stimulation effectively, although they have not consciously associated it with certain neuropedagogic concepts or

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neurocognitive mechanisms. The differences in comprehension characteristics are also evident. Respondents 1 (R1) showed a tendency towards basic conceptual understanding, such as the introduction of neuropedagogic terms and their relationship to brain function, but were not fully integrated in systematic pedagogical reflection. On the other hand, R2 features more functional and applicative understanding, reflected in the ability to relate students' learning readiness, meaningful experiences, and emotional management into daily learning practices. However, the two understanding profiles have not yet reached the stage of deep theoretical reflection related to key concepts of educational neuroscience, such as brain plasticity, neural connectivity, emotion regulation by the limbic system, and the role of the prefrontal cortex in decision-making and attention control. These findings suggest that the main challenge in the implementation of neuropedagogy in primary schools does not lie in the resistance or rigidity of learning practices, but rather in the limitations of educational neuroscience literacy. The practice that has been running has actually supported the optimization of students' brain function, but it has not been supported by adequate scientific awareness. As a result, effective learning strategies are still contextual and intuitive, and have the potential to be inconsistent if not reinforced by systematic theoretical understanding.

Theoretical and Practical Implications

Theoretically, the results of this study strengthen the argument that the gap between educational neuroscience and learning practice in elementary school is not a gap in practice, but rather a conceptual literacy gap. Neuropedagogy as an interdisciplinary field has developed rapidly in academic studies, but the transfer of knowledge to the pedagogical realm is still not optimal. These findings enrich the educational neuroscience discourse by showing that brain-based learning practices can grow naturally from teaching experiences, albeit without a strong terminological and theoretical foundation.

Practically, this study confirms that teachers have very strong pedagogical capital to implement neuropedagogic in a more targeted manner. Strengthening neuroscience literacy through professional training, scientific evidence-based reflection, and the integration of neuroscience in

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curriculum development has the potential to significantly improve the quality of learning. This approach does not require radical changes to existing teaching methods, but rather encourages a process of scientific reflection on effective practices.

Thus, efforts to bridge educational neuroscience and learning practices in the classroom can start from strengthening teachers' scientific awareness of the neurobiological basis of the learning strategies that have been implemented. When teachers understand the neurocognitive reasons behind the effectiveness of a strategy, learning is no longer purely intuitive, but becomes conscious, measurable, and sustainable. This condition ultimately supports the cognitive, emotional, and social development of elementary school students more optimally and is based on how the human brain works. The following is a table of Synthesis of Mixed Methods Findings on the Neuropedagogic Dimension of Elementary School Teachers.

Table 1. Synthesis of Findings

Neuropedagogic Dimension	Quantitative Data (Excel Score)	Qualitative Data (Interview & Discussion Results)	Analysis Synthesis (S3 Level)
Emotional Readiness (Neuro-Emotional)	84.6% (Very High)	R2 builds a positive atmosphere, lowers emotional tension, and ensures readiness to learn through *ice breaking*.	This practice validates the theory of *Affective Neuroscience*. The teacher mitigates the work of the amygdala to optimize the *Prefrontal Cortex*.
Multisensory & Contextual	76.9% (High)	The use of video, realia (plant) media, simulation of the digestive system, and photosynthesis experiments.	There is a strengthening of neural networks through the interaction of senses and the environment (*Embodied Cognition*). A biological bridge between the outside world and the sensory cortex.
Attention & Focus (Brain Breaks)	67.3% - 69.2% (High)	The use of the "Focus Tap" strategy, singing, marker play, and	Reticular *Activating System* (RAS). Teachers intuitively manage the attention *span*

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		material segmentation (10-20 minutes).	*limitations of* elementary school students.
Neuropedagogic Literacy	High on Practice	R1 & R2 feel like they've heard the term, but their understanding is still at the *surface level*.	Unconscious *competence* occurs. Teachers have a strong basic capital of pro-brain practice but require systematic theoretical deepening.

CONCLUSION

This study shows that the learning practices of primary school teachers are basically aligned with the principles of educational neuroscience, although the conceptual understanding of neuropedagogic is still at the surface level. Teachers consistently implement learning strategies that support emotional readiness, multisensory engagement, and student attention management, which neurobiologically contributes to the optimization of brain function in the learning process. These findings confirm that the application of brain-based learning in the classroom is not always born from explicit mastery of neuroscience theories, but can be developed intuitively through pedagogical experience. The results of quantitative and qualitative data synthesis revealed that the main gap in the implementation of neuropedagogy in elementary schools does not lie in the resistance of practice, but in the limitations of educational neuroscience literacy. Learning practices that have been effective have the potential to become inconsistent and less measurable if they are not supported by systematic theoretical understanding. Therefore, strengthening teachers' neuropedagogic literacy is a strategic need to ensure the sustainability and quality of learning implementation that is in harmony with how the brain works. Overall, this study emphasizes that efforts to bridge educational neuroscience and learning practice do not have to start from radical changes in teaching methods, but through a process of scientific reflection on existing practices. When teachers understand the neurocognitive basis of the learning strategies applied, learning will develop to be more conscious, directed, and sustainable in supporting the cognitive, emotional, and social development of elementary school students.

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