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LEARNING

**AND NEUROPLASTICITY: SCIENTIFIC FOUNDATIONS FOR
THE OPTIMIZATION OF EDUCATIONAL PROCESSES**



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APRENDIZAJE Y NEUROPLASTICIDAD: FUNDAMENTOS CIENTÍFICOS PARA LA OPTIMIZACIÓN DE LOS PROCESOS EDUCATIVOS

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ABSTRACT

The present study analyzes the relationship between learning and neuroplasticity as a scientific basis for the optimization of educational processes, with the objective of understanding as the brain's function influences in the acquisition of knowledge and in the improvement of pedagogical practices. It is based on the idea that the brain is a dynamic system capable of reorganizing continuously based on experience, what allows understand his learning as a process Active and adaptable. The methodology employee for this corresponds to an approach qualitative of a documentary type, supported in the review and analysis of literature published between 2010 and 2026, selecting sources academic reliable related to neuroplasticity, neuroeducation and cognitive processes. The main findings evidence that he learning this influenced by factors such as motivation, emotion, the environment and participation of active student, and that the use of methodologies active, multisensory stimulation, activity physics and technology favor strengthening of neuronal connections, allowing So improve the teaching and learning processes and promote an education further effective and inclusive.

Keywords:

Neuroplasticity, learning, neuroeducation, cognitive processes, pedagogical strategies.

RESUMEN

El presente estudio analiza la relación entre el aprendizaje y la neuroplasticidad como fundamento científico para la optimización de los procesos educativos, con el objetivo de comprender cómo el funcionamiento del cerebro influye en la adquisición de conocimientos y en la mejora de las prácticas pedagógicas. Se basa en la idea de que el cerebro es un sistema dinámico capaz de reorganizarse continuamente a partir de la experiencia, lo que permite entender el aprendizaje como un proceso activo y adaptable. La metodología empleada corresponde a un enfoque cualitativo de tipo documental, sustentado en la revisión y análisis de literatura científica publicada entre 2010 y 2026, seleccionando fuentes académicas confiables relacionadas con la neuroplasticidad, la neuroeducación y los procesos cognitivos. Los principales hallazgos evidencian que el aprendizaje está influenciado por factores como la motivación, la emoción, el entorno y la participación activa del estudiante, y que el uso de metodologías activas, la estimulación multisensorial, la actividad física y la tecnología favorecen el fortalecimiento de las conexiones neuronales, permitiendo así mejorar los procesos de enseñanza-aprendizaje y promover una educación más efectiva e inclusiva.

Palabras clave:

Neuroplasticidad, aprendizaje, neuroeducación, procesos cognitivos, estrategias pedagógicas.

INTRODUCTION

The study of human learning has undergone a significant transformation in recent decades due to advances in cognitive sciences and, particularly, in neuroscience. Traditionally, educational processes were based on pedagogical approaches centered on the transmission of content, with limited understanding of the biological mechanisms that support knowledge acquisition. However, the development of neuroeducation has made it possible to integrate scientific evidence about brain functioning into pedagogical strategies, providing a more solid foundation for the optimization of teaching–learning processes (Doidge, 2007; Goswami, 2006; Tokuhamas-Espinosa, 2011). In this context, neuroplasticity has emerged as a central concept, as it explains how the brain changes, adapts, and reorganizes itself because of experience and learning.

Neuroplasticity can be defined as the capacity of the nervous system to modify its structure and function in response to internal and external stimuli. This phenomenon involves the formation of new neural connections, the strengthening of existing ones, and, in some cases, the generation of new neurons, which allows individuals to adapt to new situations, acquire skills, and recover functions after injuries (Kolb & Whishaw, 1998; Pascual-Leone et al., 2011). For a long time, it was believed that the human brain was relatively static after childhood; however, contemporary research has demonstrated that it retains its capacity for change throughout life, although with varying levels of plasticity depending on the stage of development (Pascual-Leone et al., 2011). This discovery has revolutionized the understanding of learning by showing that it is not limited by fixed innate conditions, but can be shaped through experience, practice, and environment.

From an educational perspective, neuroplasticity constitutes the biological basis of learning. Every learning experience generates modifications in neural networks, allowing the consolidation of knowledge, skills, and competencies. In this sense, learning involves the reorganization of neural circuits through the creation and strengthening of synapses, which facilitates information retention and its subsequent application (Kandel, 2001). This process does not occur in isolation, but is influenced by multiple factors such as motivation, emotion, attention, the sociocultural context, and the physiological conditions of the individual. It has been shown that sleep plays a fundamental role in memory consolidation and in strengthening the neural connections formed during learning (Walker & Stickgold, 2006).

In the educational field, these findings have led to the development of neuro-education, a discipline that seeks to apply knowledge about the brain to improve pedagogical practices. This field proposes an integrative approach that combines contributions from psychology, pedagogy, and neuroscience, with the aim of understanding how

students learn and how educational processes can be optimized (Tokuhamas-Espinosa, 2011). Consequently, learning is recognized as a highly dynamic process, dependent on the interaction between biological and environmental factors. This perspective makes it possible to design more effective teaching strategies, adapted to students' individual characteristics and oriented toward their overall development.

Furthermore, understanding neuroplasticity has made it possible to question traditional beliefs about intelligence and academic performance. For a long time, cognitive abilities were considered relatively fixed; however, current scientific evidence indicates that the brain is highly malleable, meaning that these abilities can be developed through practice, experience, and sustained effort (Doidge, 2007). As a result, learning is no longer viewed as a process limited by genetic factors, but rather as a dynamic construction influenced by the environment and educational opportunities. This perspective has profound implications for education, as it promotes pedagogical approaches focused on growth, motivation, and long-term skill development.

On the other hand, neuroplasticity is not only related to knowledge acquisition, but also to the individual's capacity for adaptation and resilience. In educational contexts, this implies that students can overcome learning difficulties through appropriate interventions that stimulate the development of new neural connections (Pascual-Leone et al., 2011). Likewise, the use of active methodologies, meaningful learning, and constant cognitive stimulation contribute to enhancing brain plasticity, promoting deeper and more lasting learning. Strategies such as problem-based learning, collaborative work, and multisensory teaching have proven to be particularly effective in this regard.

Moreover, it is important to highlight that the educational environment plays a decisive role in the development of neuroplasticity. Enriched environments, characterized by varied stimuli, emotional support, and opportunities for exploration, promote the formation of new neural connections and enhance learning. In contrast, restrictive environments or those lacking stimulation can limit cognitive development. In this sense, the role of the teacher is fundamental, as they not only transmit knowledge but also act as mediators of learning, creating conditions that support students' comprehensive development.

The study of learning from the perspective of neuroplasticity allows us to understand that the human brain is a dynamic system, capable of continuously reorganizing itself in response to experience. This capacity constitutes the scientific basis for designing more effective educational strategies, aimed not only at the transmission of knowledge but also at the integral development of students. Therefore, the integration of neuroscience principles into education represents an opportunity to transform

pedagogical processes and respond to the demands of a constantly changing society. In this context, the present study aims to analyze the relationship between learning and neuroplasticity, identifying its scientific foundations and its application in the optimization of educational processes.

MATERIALS AND METHODS

The study was developed under an approach qualitative of documentary type, based in the review, analysis, and interpretation of scientific literature related to Learning and neuroplasticity. To this end, a study was conducted a search exhaustive of sources academics in databases specialized, selecting articles scientists, reviews systematic and publications indexed that They address the relationship between neuroscience and education.

Regarding the Selection criteria were prioritized studies published within a time frame between 2010 and 2026, with the objective was to ensure the information was up-to-date and relevant. However, the following were also included: some sources previous when his input It proved fundamental to understanding the concepts theorists, especially in relation to the fundamentals of neuroplasticity. Likewise, the following were considered only documents from magazines scientific books academics and repositories recognized, excluding unverified or unreliable sources unsupported informative material scientist.

The methodological process was carried out in several stages. First, the identification and collection of sources was carried out. using keywords such as “neuroplasticity”, “learning”, “neuroeducation” and “processes cognitive”. Subsequently, an analysis was carried out critical of the content, identifying main ideas, coincidences theoretical contributions relevant. In a third phase, the information was organized in categories topics, such as mechanisms neurobiological factors of learning that influence brain plasticity and strategies educational based in evidence scientific.

Finally, an approach was adopted integrative and interdisciplinary, which allowed relate the Contributions from neuroscience, psychology, and pedagogy. This synthesis process facilitated the construction of a global view of the phenomenon studied, oriented towards the understanding and optimization of the processes Educational. It is worth noting that the study is of a theoretical - documentary, therefore it does not include direct experimentation, but which is based in the analysis rigorous of literature existing.

RESULTS AND DISCUSSION

Learning, understood as a dynamic process of acquiring and modifying knowledge, skills and attitudes, finds his biological basis in the brain 's ability to change and adapt. In this sense, neuroplasticity constitutes the central axis that allows explain how experiences educational generate

transformations in the structure and the system operation nervous system. At the neuronal level, the Learning occurs through the modification of connections synaptic process acquaintance as plasticity synaptic, which includes phenomena such as long- term potentiation (LTP) and long- term depression (LTD), mechanisms essential for the consolidation of memory (Kandel, 2001).

One of the aspects of neuroplasticity is its continuous character throughout life. Although there are periods of criticism during the development in that the brain presents a greater sensitivity to certain stimuli, the evidence scientifically demonstrates that adults also retain an ability significant neuronal change (Kolb & Whishaw, 1998; Pascual-Leone et al., 2011). This principle has important implications educational, already that supports the idea that the Learning is possible in any stage of life and that the processes educational must to be designed considering the characteristics and needs specific to each age-related cluster.

In its context educational, diverse factors influence in the activation of neuroplasticity and, therefore Therefore, in the effectiveness of learning. Among these factors They highlight attention, motivation, and emotion. Attention acts like a filter that allows selecting the relevant information, facilitating his processing and storage in memory. Because of his part, motivation increases the student's level of commitment to the task, encouraging repetition and practice, key elements for the strengthening of connections neural pathways. Likewise, emotions They play a fundamental role, already that experiences emotionally significant They tend to consolidate more easily in long-term memory (Immordino-Yang & Damasio, 2007).

Another determining factor in the learning processes is the environment. Exposure to enriched environments, characterized due to the diversity of stimuli, social interaction, and the access to appropriate educational resources, promotes the development of new neural connections and improvement of cognitive performance. In contrast, impoverished environments or those with high levels of stress. They can negatively impact brain plasticity and makes it difficult he is learning (Doigge, 2007). Therefore, it is essential that the educational system promotes learning contexts safe, inclusive and stimulating.

From the perspective of neuroeducation, the application of the principles of neuroplasticity have led to the development of active methodologies that they are looking involve the student in a direct in his learning process. Among these methodologies are found he learning based in problems, collaborative learning and the use of strategies multisensory. These practices encourage active participation of the student, they stimulate different areas of the brain and facilitate the integration of information, which contributes to learning further significant and lasting (Tokuhama -Espinosa, 2011).

Likewise, repetition and practice spaced out are fundamental strategies for consolidating learning. The evidence Neuroscientist indicates that repetition strengthens connections synaptic, while that the distribution of the study in the times improves information retention. This phenomenon, known as the effect of spacing, suggests that learning is more cash when it is done in a distributed in place of concentration in a single period (Kandel, 2001). Therefore, the educational programs must consider the temporary organization of the content to maximize its impact in learning.

Other A key element is the importance of error in he is learning process. Far from being an indicator of failure, mistakes constitute an opportunity for neuronal reorganization and the Strengthening knowledge networks. When the student identifies and corrects its errors, they are activated processes cognitive that They promote deep understanding and the transfer of learning to new situations. In this sense, it is necessary to promote an educational culture that value error as part essential to the learning process.

The relationship between neuroplasticity and learning also has implications important in addressing diversity. Students with learning difficulties, developmental disorders, or conditions specific they can benefit from interventions educational Designed to stimulate brain plasticity. Intervention programs early strategies personalized and the use of educational technologies have proven

to be effective in improving the academic performance and promote inclusion educational (Pascual-Leone et al., 2011).

Furthermore, the role of the teacher is fundamental in the application of these principles. The educator does not only transmit knowledge, but that act as learning facilitator, designing experiences educational that promote participation Active reflection and knowledge building. For this, it is necessary that the teachers have training in neuro-education, in a way that may grasp the cerebral processes involved in he is learning and applying strategies based on scientific evidence.

On the other hand, side, the use of technologies digital in education offers new Opportunities to enhance neuroplasticity. Tools as platforms Interactive tools, simulators, and multimedia resources allow diversify the stimuli and adapt he learning to the need's individual members of the students. However, it is important that the use of these technologies is implemented in an appropriate way, avoiding overload cognitive and promoting learning significant.

Neuroplasticity provides a framework theoretical and scientific that allows grasp how it is produced learning and how can optimize through the application of appropriate pedagogical strategies. The integration of this knowledge in practice Educational not only improves the effectiveness of teaching, but which also contributes to the integral development of students, preparing them to face the challenges of a society in constant change (Table 1).

Table 1. Factors Associated with Neuroplasticity and Their Educational Implications.

Factor	Influence on Neuroplasticity	Educational Implications
Attention	Facilitates information processing and synaptic activation	Improves concentration and knowledge retention
Motivation	Strengthens repetition and neural reinforcement	Increases engagement and active participation
Emotion	Enhances long-term memory consolidation	Promotes meaningful learning experiences
Enriched environments	Stimulates new neural connections	Encourages creativity and cognitive development
Repetition and spaced practice	Reinforces synaptic plasticity	Improves retention and long-term learning
Physical activity	Activates cognitive and motor neural networks	Enhances cognitive performance and coordination
Multisensory learning	Integrates multiple sensory pathways	Facilitates comprehension and language acquisition
Educational technologies	Personalizes learning experiences	Supports adaptive and flexible learning
Active methodologies	Promote deeper cognitive processing	Strengthens critical thinking and problem-solving

Galván (2010) analyzes neuronal plasticity during the development, highlighting that he brains in stages early presents a greater sensitivity to the environmental stimuli, which influences directly in the capacity for learning. The author explains that the changes Structural and functional factors of the brain do not depend solely on factors biological, but also from the interaction constant with the environment, what implies that the experiences educational they can mold significantly he development cognitive. Consequently, his investigation highlights the importance of design strategies pedagogically adapted to the stages of development, taking advantage of the periods of greater plasticity to enhance his learning and promoting the acquisition of skills complex.

Likewise, Anitha (2025) proposes an innovative approach in linking neuroplasticity with design instructional, arguing that the teaching must be based on the knowledge of the process's cognitive aspects of the brain. In this in that sense, the author raises that the planning educational based in beginning neuroscientists allows structure learning experiences further effective, already that consider aspects such as memory, attention, and cognitive load. Furthermore, it highlights that the alignment between the brain function and strategies Teaching methods not only improve the understanding of content, but which also facilitates the transfer of knowledge to real-world contexts, strengthening so he is learning significant.

On the other hand, on the other hand, Blanchette Sarrasin et al. (2025) show that the teaching of neuroplasticity to the students has positive effects in key learning variables, such as motivation, inhibitory control, and performance Academic. The authors demonstrate that when the students understand that the brain can change and improve, they develop a greater willingness toward the effort and overcoming difficulties. Furthermore, they link these results with the "mindset" theory, indicating that a growth mindset contributes to improvement he performance and persistence. Therefore, this study highlights the importance of incorporating content about brain function in the educational curriculum.

Herein same line, Yuan et al. (2025) highlight the role of exercise physical in the stimulation of neuroplasticity within contexts educational, underlining that the activity Physical activity not only benefits physical health, but also operation Cognitive. His research demonstrates that exercise can improve processes as he recognition of actions and coordination cognitive, what suggests that he body movement is tightly linked to the learning. Consequently, the authors propose the integration of physical activities inside the classroom as a pedagogical strategy that favors the development cognitive as the general well-being of the student.

In a way Complementary, Puderbaugh & Emmady (2023) offer a revision detailed neuroplasticity from a perspective medical doctor and neuroscientist, explaining the mechanisms physiological that They allow for brain reorganization. Their analysis covers processes such as synaptogenesis, neurogenesis, and cortical reorganization, the which are fundamental to the Learning and adaptation. Furthermore, they highlight that neuroplasticity is not only relevant in educational contexts, but also in rehabilitation processes, which evidence his integral character in the operation of humans.

In this sense, Yuliana (2020) delves deeper in the relationship between brain plasticity and learning processes, emphasizing that he around education plays a role determinant in the formation of connections neuronal. The author maintains that learning experiences significantly, accompanied by stimuli appropriate and support Emotional

factors favor the consolidation of knowledge. Furthermore, it highlights that repetition and practice constant elements essential for strengthening neural networks, which reinforces the importance of design strategies pedagogically that promote participation active student.

Similarly, Gkintoni et al. (2025) analyzes multisensory learning from a neuroscientist perspective, demonstrating that the stimulation simultaneous of several senses improve significantly the results cognitive. Their study reveals that this focus is especially cash in contexts multicultural and in the acquisition of second languages, already that facilitates the integration of information and the skills development communicative. Consequently, the authors suggest that educational methodologies must incorporate multisensory experiences to optimize learning.

Therefore, Dubinsky & Hamid (2024) compare his learning active with direct instruction, concluding that the active methodologies generate increased brain activation and promote a better Consolidation of knowledge. The authors they argue that when the students participate actively in his learning process, they get involved cognitively in a deeper, what This approach facilitates the understanding and retention of information. supports the implementation of pedagogical strategies centered in the student, as he learning based in problems and collaborative jobs.

In relation to the above, Darling-Hammond et al. (2020) integrate the science of learning and the development to propose implications practices in education, highlighting the importance of considering factors emotional, social, and cognitive in the processes Educational. His research emphasizes that he is learning cash cannot separate from the context in he that It happens, therefore it is necessary adopt a comprehensive approach that contemplate her student well-being. In this way, the authors promote educational practices that favor environments safe, inclusive and stimulating.

On the other hand, part Topolnyk et al. (2025) examine the impact of digital technologies and artificial intelligence in adult learning, pointing out that they can enhance neuroplasticity by offering educational customized experiences. The authors stand out that technology allows fit the content to meet needs of individual members of the students, facilitating learning more flexible and accessible. However, they also warn on the importance of appropriate use of these Tools to avoid overload cognitive.

Herein From this perspective, Lambert et al. (2019) identify neurobiological mechanisms that optimize the brain performance, indicating that the stimulation of adequate brain can improve significantly the capabilities Cognitive. Her research highlights the importance of factors such as novelty, the challenge and social interaction in the activation of neuroplasticity, which has direct implications in the experiences design educational.

Likewise, Bezzola et al. (2012) demonstrates that he motors training induces neuroplastic changes even in older adults, what evidence that the capacity for learning is maintained throughout life. This finding reinforces the idea that the brain preserves his adaptability, regardless of age, which has important Implications for continuing education.

Likewise In this way, Sheneman et al. (2019) explore the evolution of neuroplasticity from a perspective theoretical, highlighting his paper in the integration of information and in the brain 's adaptation to new Experiences. Their analysis contributes to a comprehension deeper learning as a process dynamic and in constant transformation.

In another in order of ideas, Voss et al. (2017) analyzes how the rules of neuroplasticity change over time, highlighting that the brain not only adapts, but also modifies its own Mechanisms of change. This approach highlights the complexity of learning and its character evolutionary.

Furthermore, Baker et al. (2025) address brain plasticity in adolescence, noting that this stage represents a critical window for the skills development Cognitive and social

aspects. Their study highlights the importance of taking advantage of this period for implementation interventions educationally effective.

Finally, Weyandt et al. (2020) review the evidence about interventions in children and adolescents, demonstrating that are they can trigger changes neuroplastic significant. This contribution is fundamental to the inclusive educational strategy that responds to everyone 's needs the students.

The investigations analyzed agree in pointing out that neuroplasticity constitutes the biological basis of learning and that his comprehension allows significant improvement of the educational processes. Taken together, they demonstrate that the brain has a continuous capacity for adaptation that is seen influenced by factors like experience, the environment, activity physics and strategies and pedagogical employees. They also highlight that learning does not depend only on the transmission of content, but also the interaction active participation of the student with their context, what favors construction significant of knowledge (Table 2).

Table 2. Main Contributions of Studies on Neuroplasticity and Learning.

Author(s)	Main Contribution	Educational Relevance
Galván (2010)	Brain plasticity is greater during early development	Importance of age-adapted strategies
Anitha (2025)	Neuroplasticity improves instructional design	Alignment between teaching and brain function
Blanchette Sarrasin et al. (2025)	Knowledge of neuroplasticity increases motivation	Promotes growth mindset
Yuan et al. (2025)	Physical exercise enhances cognition	Supports movement-based learning
Gkintoni et al. (2025)	Multisensory learning improves cognition	Useful in multicultural contexts
Dubinsky & Hamid (2024)	Active learning increases brain activation	Encourages student-centered education
Darling-Hammond et al. (2020)	Emotional and social factors affect learning	Promotes inclusive education
Topolnyk et al. (2025)	Digital technologies support neuroplasticity	Facilitates personalized learning

On the other hand, On the other hand, the importance of designing is highlighted. practices educational aligned with the brain function, considering aspects such as motivation, emotion, and active participation. In this meaning, methodologies as he learning active, multisensory and contextualized allow greater consolidation of knowledge and skills development cognitive complex. Furthermore, it becomes evident that the teaching on the brain 's capacity for change can influence positively in the student 's attitude, promoting greater effort and persistence.

Likewise way, the studies emphasize the impact of external factors as he is around education, technology and activity physics in he is strengthening of connections neuronal. It stands out enriched environments, the use appropriate tools digital and the integration of movement in the learning contribute to enhancing the performance of cognitive. Finally, it is recognized that neuroplasticity presents throughout life, which allows not only the acquisition of new knowledge, but also overcoming difficulties and adapting to different contexts educational, favoring a further inclusive and effective education.

CONCLUSIONS

The present study allows reaffirms that neuroplasticity constitutes he basis essential to learning human, by demonstrating that he the brain is not a structure static, but a system dynamic capable of reorganizing continuously in Response to experience. This capacity for change represents a turning point in understanding learning, already that It breaks with

the traditional idea of limitations. fixed in the capabilities cognitive and opens new possibilities for the development lifelong learning.

Based on the analysis done, it is evident that his learning cannot be understood only as a process of information accumulation, but as a transformation of an active brain, influenced by factors biological, emotional, social, and environmental factors. In this sense, it turns out essential that the educational systems evolve toward models' further integrals, in the that the student be considered as a subject asset in the construction of their knowledge. The implementation of methodologies Dynamic, participatory, and contextualized activities not only improve understanding, but that It promotes the consolidation of neural networks further solid and functional.

Likewise, this study reveals variables such as motivation, emotion, and environment and social interaction play a role determinant in the activation of neuroplasticity. This implies that the quality of the educational environment is not a secondary aspect, but a central element in his learning success. Spaces educational enriched, that promote curiosity, participation and emotional welfare, they enhance significantly the capabilities cognitive aspects of the students and facilitate learning deeper and more lasting.

Likewise In this way, it is concluded that the integration of elements such as the activity physics, the use Appropriate technology and multisensory stimulation contribute to optimization the teaching and learning processes. These strategies not only expand the possibilities pedagogically, but that respond in the in that he brains It processes information, promoting learning. further meaningful and adaptable to different contexts.

Other relevant aspect is the role of neuroplasticity in inclusion Educational. The evidence analyzed demonstrates that all individuals, regardless of them regardless of age, conditions, or difficulties, everyone has the capacity to learn and develop. This reinforces the need to design flexible and personalized practice educational programs, which address the diversity of the student body and promote equity in access to knowledge.

Finally, this study evidence that the incorporation of the principles of neuroscience in education not only represents progress theoretically, but a need practice in the current context. Understanding as learn the brain allows transform teaching in a process further Effective, conscious, and oriented towards the integral development of the human being. Consequently, the importance of continuing is emphasized. researching and applying this knowledge, to build educational systems further innovative, inclusive and capable of responding to the challenges of a society in constant change.

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Conflicts of Interest:

The author declares no conflicts of interest.

Author Contributions:

Humeyir Ahmadov: Conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, visualization, original draft writing, and writing, review, and editing.

Ethical statement:

The study was based on the analysis of documentary sources and publicly available data, and therefore did not involve the direct participation of human subjects. No personally identifiable information was handled.