v. 5, n. 7, 2025

Journal of
Engineering
Research

Acceptance date: 06/08/2025

NEUROPLASTICITY BASED ON MATHEMATICAL PRACTICE IN ACADEMIC ENGINEERING

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Abstract: Neuroplasticity refers to the brain's ability to reorganize and adapt based on the experiences and stimuli it receives. This article discusses the relationship between neuroplasticity and mathematical practice in the context of higher education in Engineering, highlighting the relevance of this connection for strengthening learning and academic performance. The topic is justified by the cognitive demands of exact sciences courses and recent discoveries in neuroscience about the brain's ability to reorganize itself based on stimuli such as mathematical study. The main objective is to demonstrate how the systematic practice of mathematics can stimulate structural and functional changes in the brains of engineering students, favoring logical reasoning, working memory and attention. To this end, an exploratory bibliographical study was carried out, with a survey of articles published between 2009 and 2025 on the ScienceDirect, Scopus, PubMed, SciELO and Google Scholar databases. The selection of studies used the descriptors "neuroplasticity", "mathematics", "learning" and "engineering", always combined with the Boolean operator "AND". The results show that continuous engagement with mathematical activities strengthens neural connections and improves cognitive efficiency. Evidence highlights that this type of practice promotes the activation of specific brain areas and contributes to the development of essential skills for training engineers. In addition, by understanding the concept of neuroplasticity, students tend to adopt a growth mindset and become more resilient in the face of academic challenges. Thus, integrating mathematical practices in the light of neuroscience can transform the teaching-learning process in engineering, promoting more solid, adaptable and effective learning.

Keywords: Learning; Engineering; Mathematics; Neuroplasticity

INTRODUCTION

Neuroplasticity is the brain's ability to reorganize itself structurally and functionally in response to internal or external stimuli, making it possible to form, strengthen or eliminate synaptic connections throughout life. This phenomenon challenges the old notion that the human brain, upon reaching maturity, becomes rigid and immutable. Recent research shows that the central nervous system has plasticity not only during development, but also in adults, promoting continuous learning and adaptation to new experiences (COSTA, 2023).

In the field of neuroscience, neuroplasticity is considered the biological basis of learning. According to Afolabi (2024), this brain capacity allows cognitive skills to be developed or improved through deliberate and targeted practice, contradicting the idea of innate and fixed talents. When stimulated by meaningful educational experiences, such as studying mathematics, new neural networks are created or strengthened, making the brain more efficient at processing, understanding and applying information. This plasticity is therefore a powerful tool for transforming teaching and learning in the academic context.

Mathematical practice, especially in higher education, plays a decisive role in the development of neuroplasticity. According to Holtmaat and Svoboda (2009), the adult brain continues to be able to remodel its synaptic structures in response to experience, especially when involved in tasks that require logical reasoning and problem solving. Studying and repeating mathematical exercises stimulates structural changes in dendritic spines and axonal buttons, creating more efficient neural pathways. Thus, constant practice not only strengthens cognitive skills, but also contributes to an increase in the ability to store and retrieve information.

In addition, active engagement in mathematical solutions favors the growth of new neural connections, which is essential for the acquisition and consolidation of knowledge. Afolabi (2024) reinforces that consistent mathematical activities generate changes in the brain areas associated with numerical processing and cognitive control. and cognitive control, fundamental factors for academic performance in courses such as engineering.

Understanding neuroplasticity also contributes to a change of mentality in students, favoring the development of a growth mindset. According to Blanchette Sarrasin et al. (2018), teaching the concept of neuroplasticity can generate significant improvements in motivation and performance, especially in mathematics. When students understand that intelligence is malleable, they become more perseverant in the face of challenges, which makes them better able to develop the advanced mathematical skills needed to succeed in engineering.

Teaching math mediated by neuroscience also allows teachers to better understand students' learning styles and multiple intelligences, making their practices more inclusive and effective. As Araújo, Menezes and Bezerra (2019) show, the application of neuroscientific knowledge in the classroom contributes to a more personalized didactic approach, stimulating logical thinking and students' interest in the subject. This approach has the potential to promote greater involvement, motivation and understanding on the part of students, increasing their ability to solve complex problems with greater confidence and autonomy.

Based on this context, the aim of this article is to investigate the relationship between mathematical practice and the development of neuroplasticity in engineering students in the academic environment. It seeks to demonstrate how the constant practice of mathematical exercises can contribute to more efficient and agile learning of technical subjects, promoting better performance and preparation for the challenges of engineering training.

THEORETICAL FOUNDATION

FOUNDATIONS OF NEUROPLASTICITY IN THE CONTEXT OF LEARNING

Neuroplasticity is one of the most revolutionary concepts in modern neuroscience and refers to the brain's ability to modify its structure and function in response to environmental experiences and stimuli. This plasticity is essential for learning, as it allows the brain to create, strengthen or eliminate connections between neurons - a phenomenon known as synaptogenesis (COSTA, 2023). This process takes place throughout life, albeit with variations depending on age and the type of stimulus received.

According to Costa (2023), learning is a neurobiological phenomenon that involves changes in the central nervous system, promoted by experiences and stimuli. These changes occur through the formation of new synapses or the strengthening of existing connections, especially between neurons located in regions involved in attention, memory and executive functions. This means that learning is not just about acquiring information, but literally transforming the brain.

Brain plasticity manifests itself in different ways and at different levels. It can be synaptic, involving changes in the strength of connections between neurons, or structural, involving the formation and elimination of synapses and even dendritic and axonal branches. In vivo imaging studies show that, even in adult brains, dendrites and axons undergo subtle but significant reconfigurations in response to learning and stimulation (HOLTMAAT; SVOBODA, 2009).

In addition, the dynamics of neural circuits have a modular architecture that favors adaptation and learning. Bassett et al. (2011) demonstrated that the functional connectivity of the human brain during the learning process is organized in modules, i.e. groups of brain regions that interact strongly with each other, but with little interaction with other regions. This modular organization provides flexibility and robustness to the nervous system, allowing for localized adjustments without compromising the overall stability of the brain network.

The flexibility of these modular networks is a key element of neuroplasticity. According to experiments by Bassett et al. (2011), during the learning of simple motor skills, the composition of these neural communities changes over time. This dynamic behavior reveals the brain's ability to reorganize its networks as new tasks are introduced and assimilated. The amount of flexibility observed at a given was even able to predict learning success in future sessions.

At the cellular level, neuroplasticity takes the form of structures such as dendritic spines, which are small projections of the dendrites responsible for receiving synaptic signals. Holtmaat and Svoboda (2009) identified that these spines show different behaviors: while some remain stable for months, others appear and disappear in a few days. This dynamic is critical for the formation of lasting memories, since new spikes can represent the creation of new memories, while their elimination can be related to forgetting or adaptation to new contexts.

In a broader context, Costa (2023) points out that neuroplasticity is not homogeneous: it depends on life history, motivation, the type of stimulus and the stage of development the individual is in. Although there are critical periods - time windows in which the brain is more receptive to certain learning - the ability to learn is maintained throughout life, albeit with different characteristics at each stage.

Still in the field of neuroscience applied to learning, Costa (2023) reinforces the importance of solid connections between concepts and content as the basis for lasting learning. These connections occur when different brain areas are activated simultaneously, forming integrated neural networks. Pedagogical strategies that encourage critical thinking and the association of ideas are therefore fundamental tools for enhancing neuroplasticity.

Bassett et al. (2011) also draw attention to the fact that learning modifies not only the structure of brain networks, but also their dynamics. They demonstrated that, as individuals become more proficient at a task, the flexibility of the networks decreases, reflecting a consolidation of acquired skills. This is evidence of a learning cycle: at first, there is a great deal of variability and experimentation; then, with mastery of the task, the brain optimizes its connections, making them more efficient.

THE RELATIONSHIP BETWEEN NEUROPLASTICITY E HIGHER COGNITIVE FUNCTIONS

Neuroplasticity is directly related to the development and modulation of higher cognitive functions such as memory, attention, executive control and problem solving. One of these higher cognitive functions that benefits from brain plasticity is working memory. According to Wang (2020), training that requires active manipulation of information - such as mental calculation using the abacus - favors the strengthening of neural networks associated with the storage and temporary manipulation of data. During this type of training, participants need to retain numbers mentally and update them quickly as they perform operations, which continually challenges the working memory system, resulting in gains that are transferable to other tasks that require simultaneous reasoning and retention of information.

Wang (2020) also demonstrated that mental training with an abacus is capable of improving not only working memory, but also attentional control and the ability to switch between mental contexts - essential skills in complex academic and professional environments, such as engineering. Children who underwent long periods of training performed better in memory refreshment tests and in tasks that require rapid strategy switching. These results suggest that by challenging the brain with varied and constant stimuli, abacus training stimulates the strengthening of cognitive mechanisms that are fundamental to problem solving.

In addition, there is evidence that the type of cognitive strategy used directly affects which brain areas are activated during intellectual tasks. While people without specific training tend to use linguistic and auditory strategies, advanced users of mental calculation with an abacus show greater activation of visual and spatial regions of the brain (WANG, 2020).

In the study by Holtmaat and Svoboda (2009), it was observed that even in adult brains, synaptic circuits are capable of changing based on specific experiences. These authors demonstrated that structural changes

such as the growth of dendritic spines, occur in response to deliberate practice, which is indicative of memory formation and learning.

Finally, Costa (2023) emphasizes that the development of cognitive functions does not occur in isolation, but is deeply linked to emotions, motivation and the learning environment. Brain plasticity is only effective when the individual is engaged, interested and exposed to challenges that stimulate the brain to leave its comfort zone.

MATHEMATICAL PRACTICE AS A STIMULUS NEUROPLASTICITY

Mathematics can be understood as a language of its own, with a specific structure, symbols and logic. As with any other language, its effectiveness depends on understanding and mastering its signs. According to Albuquerque and Lima Júnior (2021), mathematics has a formal and standardized symbology, expressed through equations, graphs, tables and formulas, which allows ideas to be represented, meanings to be constructed and problems to be solved. Because this mathematical language is distinct from spoken language, it requires learning that involves not just memorizing symbols, but a deep understanding of their rules and interrelationships.

Learning mathematics, therefore, is equivalent to learning a new language: it requires the internalization of a symbolic system, which must be translated and applied to different contexts. According to Albuquerque and Lima Júnior (2021), many students have difficulties precisely because they do not master this encrypted language. This lack of symbolic fluency compromises mathematical reasoning, the interpretation of problems and, consequently, learning.

The constant practice of mathematics, in addition to facilitating familiarity with its language, acts directly on the brain structure. Afolabi (2024) points out that neuroplasticity is significantly activated when the individual engages in mathematical activities. Problem solving, especially when carried out repeatedly and significantly, induces structural and functional changes in brain regions responsible for logical reasoning, working memory and attention. In other words, mathematicians' brains change, strengthening neural connections and creating new pathways to process information more efficiently.

Menon and Chang (2021) complement this perspective by stating that mathematical learning involves the interaction of multiple neural systems, including the declarative memory system (linked to the medial temporal lobe), the cognitive control system (in the prefrontal cortex) and specific numerical representation areas (such as the posterior parietal cortex). These regions work in an integrated way and organize themselves as the student progresses in learning. This process is known as "interactive specialization" and depends heavily on frequent practice to consolidate efficient neural circuits.

Also according to Menon and Chang (2021), learning numerical concepts and skills such as addition, subtraction or solving complex problems depends on constant repetition and exposure to different types of tasks. As the student progresses, brain activity stops requiring effort from regions associated with conscious effort (such as the hippocampus) and becomes more automatic, reflecting an optimization of neural circuits.

Mathematical practice also encourages the use of more efficient cognitive strategies. As Cho et al. (apud MENON; CHANG, 2021) point out, children who practice math regularly move from counting strategies to strategies based on retrieving facts. This transition represents an advance in the development of mathematical fluency, as it allows for faster and more accurate responses, optimizing the use of memory and attention.

Another important factor is the role of focused attention and cognitive control during mathematical practice. Afolabi (2024) points out that solving mathematical problems requires more than technical knowledge: it requires concentration, emotional regulation and persistence in the face of difficulty. Active engagement with mathematical tasks promotes the development of these skills, which are transferred to other areas of academic and professional life. Students who get used to solving mathematical problems tend to develop greater tolerance for error, more patience and better strategies for dealing with challenging situations.

Mathematical learning benefits from the use of contextualized problems, which further enhances neuroplasticity. Albuquerque and Lima Júnior (2021) observed that students perform better when they solve problems linked to everyday life, as they are able to associate the abstract concepts of mathematics with real situations. This contextualization favors emotional involvement, understanding the meaning of symbols and strengthening neural connections, making learning more meaningful and lasting.

NEURO EDUCATION E TEACHINGOF MATHEMATICS AT ENGINEERING

By integrating knowledge from neuroscience, psychology and pedagogy, neuroeducation seeks to understand how the brain learns, with the aim of optimizing teaching practices. This approach has proved particularly relevant in higher education, especially in engineering courses, where the complexity of the subjects requires a high level of logical reasoning and superior cognitive skills. According to Chen and Goodwill (2022), learning in adult life is profoundly influenced by neurobiological, sociocultural and environmental factors, which directly affect neuroplasticity.

Chen and Goodwill (2022) point out that the adult brain maintains its capacity for functional and structural restructuring, provided it is exposed to appropriate stimuli. For engineers in training, this means that consistent math practice, combined with teaching methods based on neuroscience, can promote deeper and longer-lasting learning.

Mathematical practice, especially when embedded in contexts that make sense to the student, has the potential to activate important neural circuits linked to working memory, attention and problem solving. According to Afolabi (2024), this type of practice strengthens areas of the brain related to logical reasoning, facilitating the development of essential skills for working in engineering. This is even more significant when you consider that many students enter higher education with gaps in their basic education, which can be overcome through teaching strategies that respect the principles of neuroplasticity.

In addition to the practice itself, the student's environment and lifestyle also have an impact on the learning process. According to Chen and Goodwill (2022), factors such as sleep, diet and stress directly influence the functioning of the adult brain. An engineering student, for example, often faces high levels of demand and pressure, the that can compromise the neuroplasticity if not balanced with healthy habits. In this sense, neuroeducation is not limited to the content taught, but also guides the creation of academic policies and routines that favor students' well-being and cognitive health.

Another important aspect addressed by Chen and Goodwill (2022) is the concept of cognitive reserve - the idea that the brain can develop a cognitive "reserve" over time, based on accumulated experiences and learning. In the context of engineering, the continuous resolution of mathematical problems and exposure to different forms of reasoning can strengthen this reserve, making the student better able to deal with complex challenges and adapt quickly to technological and scientific changes in the profession.

Mathematics teaching based on neuroeducation also takes into account the role of metacognition - that is, the ability to reflect on one's own learning process. According to Chen and Goodwill (2022), the development of metacognitive strategies is essential for adults to become autonomous learners.

Integrating neuroeducation into the teaching of mathematics in engineering reinforces the idea that learning is a dynamic process, built on experience and continuous practice. As Menon and Chang (2021) point out, continuous mathematical learning reorganizes neural networks in an increasingly efficient way, generating not only technical knowledge, but also greater cognitive flexibility - an indispensable characteristic for engineers faced with unprecedented problems.

MENTALITY OF GROWTH E ACADEMIC PERFORMANCE

Growth mindset is a concept originating in educational psychology that describes the belief that intellectual abilities can be developed through effort, dedication and continuous practice. In contrast, the fixed mindset assumes that intelligence is an immutable and static trait. According to Blanchette Sarrasin et al. (2018), this distinction significantly influences how students respond to challenges and failures. Individuals with mindset of growth tend to face difficulties with resilience and see difficulties with resilience and see mistakes as learning opportunities, whereas those with a fixed mindset often give up in the face of obstacles because they believe their capacity is limited.

Studies show that promoting a growth mindset in the classroom can positively impact academic performance, especially when students are exposed to information about neuroplasticity. According to Blanchette Sarrasin et al. (2018), interventions that explain how the brain changes in response to learning increase student motivation, improve school results and stimulate brain activities related to effort and error correction.

The relationship between growth mindset and mathematics has been widely studied because it is a subject that carries many stigmas. Van Hoeve, Doorman and Veldhuis (2025) point out that many students believe they are not "born for mathematics", which contributes to the formation of limiting and demotivating beliefs. When these students are taught about neuroplasticity and how the brain changes with effort, they start to have a more positive attitude towards the subject. The study conducted in the Netherlands showed that after interventions based on mindset theory, students showed greater engagement, confidence and willingness to solve mathematical problems.

In addition to the increase in motivation, these interventions also promoted visible changes in classroom behavior. Students began to use more encouraging language, worked more carefully and showed more confidence when faced with mathematical difficulties (VAN HOEVE; DOORMAN; VELDHUIS, 2025). The change in attitude was not just among the students: teachers who took part in the research also reported rethinking their way of dealing with students' mistakes and difficulties, coming to value them as an essential part of the learning process.

In parallel, Araújo, Menezes and Bezerra (2019) point out that success in teaching mathematics is related not only to cognitive factors, but also to understanding the multiple ways of learning and the diverse intelligences that students possess. When teachers recognize that each student has a different learning style - be it visual, auditory or kinesthetic - and align their teaching practice with this understanding, they promote a more inclusive and motivating environment.

more inclusive and motivating environment. Developing a growth mindset, in this case, goes hand in hand with respecting the singularities of learners.

In the context of higher education, especially in engineering, this type of approach becomes even more necessary. Engineering courses require a high level of mastery of mathematics and logical reasoning, skills that often generate insecurity among students. As the studies by Van Hoeve, Doorman and Veldhuis (2025) show, highly competitive environments can lead students to adopt a fixed mindset for fear of making mistakes or not living up to expectations.

By knowing that mathematical performance is not just the result of innate talent, but of training and continuous effort, students feel more motivated to face the challenges of the course. Research by Blanchette Sarrasin et al. (2018) points out that math performance improves significantly when students come to believe that their intelligence can expand with time and practice.

What's more, the benefits of a growth mindset are not restricted to test performance. Students who develop this mindset tend to seek more autonomy, persist in the face of difficulties and take an active stance in problem-solving - fundamental characteristics for training competent and adaptable engineers (VAN HOEVE; DOORMAN; VELDHUIS, 2025).

METHODOLOGY

This article was based on exploratory bibliographical research, with the aim of gathering, analyzing and interpreting information available in scientific publications dealing with the relationship between neuroplasticity, mathematical practice and learning in the context of engineering. The choice of this type of research is justified by its ability to provide a solid theoretical basis, allowing complex and interdisciplinary concepts to be understood without the need to collect direct empirical data.

The search for articles was carried out in recognized academic databases such as ScienceDirect, Scopus, PubMed, SciELO and Google Scholar. The following keywords were used to locate the most relevant works: neuroplasticity, mathematics, learning and engineering. The terms were combined using the Boolean operator "AND" in order to ensure that the articles selected simultaneously addressed the central concepts of the study. The keywords and their related terms can be seen in Figure 1.

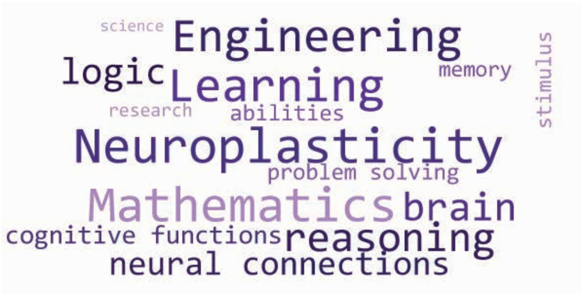

Figure 1 - Cloud of keywords used and their related terms

Source: Own elaboration

Priority was given to articles published between 2009 and 2025, written in Portuguese and English, with free access and in peer-reviewed scientific journals. The inclusion criteria involved studies that presented a theoretical or empirical basis on the role of mathematics in stimulating neuroplasticity, as well as its application in the teaching-learning process in engineering courses.

The analysis of the articles was of a theoretical nature, with an emphasis on identifying key concepts, recurring patterns and scientific evidence that would support the central proposal of the article: to demonstrate how mathematical practice, combined with knowledge of neuroplasticity, can contribute to more efficient and lasting learning in the field of engineering learning in the field of engineering. The articles used are described in Table 1 with their respective relevant information, such as: title, authors, abstract, year and relevance.

The relevance of the articles was determined based on three main criteria: applicability to the topic, theoretical scope and academic recognition. The first criterion, direct applicability to the topic of the article, refers to the extent to which the content of the study relates to the pillars of this work, i.e. neuroplasticity, mathematics, learning and engineering. Articles that address all of these topics in an interconnected way received a higher score, while those that deal with only one or two topics received a proportional score.

The second criterion evaluated was methodological breadth and theoretical depth. Articles that present a robust theoretical foundation, systematic reviews or well-structured case studies were considered more relevant than texts with a superficial or exploratory approach. This made it possible to assess not only the content, but also the quality and consistency of the research presented.

Finally, the third criterion was academic recognition, measured by the approximate number of citations the article has in scientific databases. Works widely cited in the literature were considered more influential within the field of study, while recent articles or those with low repercussions received lower scores in this respect.

Based on these three criteria, each article was classified with a level of relevance - low, medium or high - in a weighted manner. The calculation combined 50% weight for applicability to the topic, 30% for theoretical depth and 20% for the number of citations. The final value was rounded up to a qualitative scale in order to facilitate analysis and understanding of the importance of each reference in the development of this article.

CONCLUSION

Neuroplasticity, as the central concept of this study, reveals the incredible capacity of the human brain to reorganize and adapt in response to stimuli and experiences. This phenomenon, which occurs at different levels - molecular, cellular, systemic and behavioral - has profound implications for the learning process. Neuroplasticity justifies the importance of practices that involve meaningful repetition, active engagement and critical reflection by students, creating a learning environment that effectively provokes changes in students' brains.

TITLE	AUTHORS	SUMMARY	YEAR	RELEVANCE
Mathematics learning through the lens of neuroplasticity: A researcher's perspective	Afolabi, A. O.	The article explores how neuroplasticity influences mathematical learning, highlighting pedagogical practices that stimulate brain adaptability.	2024	High
Mathematical language: knowledge and use of symbology in interpreting problems	Albuquerque, A. de S.; Lima Júnior, H. G.	Investigating how teachers understand and teach mathematical language and its impact on learning.	2021	Average
Neuroscience and the teaching of mathematics: a study on learning styles and multiple intelligences	Araújo, F. G. da S.; Menezes, D. B.; Bezerra, K. de S.	Examines learning styles and multiple intelligences in mathematics teaching based on neuroscience.	2019	Medium
Dynamic reconfiguration of human brain networks during learning	Bassett, D. S. et al.	Analyzes how brain networks reconfigure during learning, using neuroimaging.	2011	Alta
Effects of teaching the concept of neuroplasticity to induce a growth mindset on motivation, achievement, and brain activity: A meta-analysis.	Blanchette Sarrasin, J. et al.	Meta-analysis on the impact of teaching neuroplasticity to promote growth mindset.	2018	Alta
Neuroplasticity and adult learning	Chen, S. H. A.; Goodwill, A. M.	Discusses how the adult brain remains adaptable, with implications for ongoing learning.	2022	High
Neuroscience and learning	Costa, R. L. S.	Addresses how neuroscience can support pedagogical practices and the learning process.	2023	Medium
Experience-dependent structural synaptic plasticity in the mammalian brain	Holtmaat, A.; Svoboda, K.	Study on experience-induced synaptic plasticity in the mammalian brain.	2009	Alta
Emerging neurodevelopmental perspectives on mathematical learning	Menon, V.; Chang, H.	Presents perspectives on brain development and mathematical learning.	2021	Alta
A review of the effects of abacus training on cognitive functions and neural systems in humans	Wang, C.	Review of how abacus training affects cognitive functions and neural structures.	2020	Medium
Fostering a growth mindset in secondary mathematics classrooms in the Netherlands	Van Hoeve, M.; Doorman, M.; Veldhuis, M.	Studies strategies to promote a growth mindset in mathematics classes.	2025	Average

Table 1 - Information relevant to the articles used

Source: Own elaboration

The results of the review indicate that the systematic practice of mathematics contributes significantly to strengthening neural connections by expanding the cognitive capacity of students in the area of exact sciences, such as engineering, generating the improvement of essential skills for academic and professional performance.

In addition, it was possible to observe that understanding the concept and mechanisms of neuroplasticity can be a strategic tool when it comes to developing more effective teaching methods. By integrating practices that challenge the brain and encourage active problem-solving, they can transform the teaching-learning process in engineering into a more dynamic, personalized and productive model, promoting learning that is more lasting, efficient and adaptable to the demands of the contemporary job market.

This study reaffirms the importance of the systematic and conscious practice of mathematics as a tool for strengthening the brain and improving the learning process. Neuroplasticity, as a dynamic and continuous phenomenon, highlights the human capacity for intellectual evolution, provided it is stimulated appropriately and consistently.

Therefore, regular mathematical practice, combined with knowledge of the principles of neuroplasticity, is an "engine" for efficiency in the practical and solid learning of of engineers. This approach represents an opportunity to build academic curricula that value both the transmission of content and the continuous development of students' cognitive abilities.

It is therefore recommended that future research explore practical interventions in the educational environment that integrate these concepts, in order to empirically validate the benefits observed in the literature and contribute to innovation in engineering education.

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