El aula sináptica: un marco de neurociencia crítica para la enseñanza del idioma inglés

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Resumen

La enseñanza del inglés en Panamá se enfrenta a diversos retos y requiere mejoras urgentes. Aunque los avances en neurociencia ofrecen una solución fiable con una amplia gama de herramientas para transformar la enseñanza del inglés, muchos docentes siguen incorporando "neuromitos" a sus clases, a menudo sin siquiera darse cuenta. Este artículo analiza críticamente estos conceptos erróneos y presenta una guía basada en la evidencia y fundamentada en la neuroplasticidad, la memoria y la atención. Tras analizar 23 estudios seleccionados mediante motores de búsqueda académica, de acuerdo con las directrices PRISMA, esta revisión identifica brechas críticas entre la investigación y la práctica. Los resultados muestran que más del 60 % de los docentes apoyan conceptos de enseñanza sin base empírica, a pesar de que existen pruebas fiables que respaldan la integración multisensorial. Los datos empíricos respaldan las prácticas de recuperación, la repetición espaciada y una carga cognitiva controlada, en lugar de continuar con la práctica masiva tradicional. Adicional a esto, la seguridad psicológica reduce significativamente el "filtro afectivo" (barrera psicológica generada por sentimientos aprensivos como la ansiedad, el miedo o la baja autoestima que impiden el procesamiento del input comprensible por los mecanismos de adquisición del lenguaje), mejorando la función del hipocampo y la retención. Por lo tanto, la evidencia demuestra que la transición hacia la enseñanza del inglés basada en la neurociencia exige más que simples talleres; requiere una base neurocientífica sólida y apoyo institucional. Por lo cual, la planificación de las clases debe priorizar la profundización del conocimiento sobre la cantidad, alineándose con

los sistemas de consolidación y reconsolidación basados en los ciclos de memoria del cerebro. Si bien la neurociencia no es una panacea, la integración de estos principios fomenta la neuroplasticidad y reduce la ansiedad. Panamá tiene la oportunidad de convertirse en líder en la transformación de las prácticas docentes en esta región si las partes interesadas colaboran en investigaciones específicas de este campo. Si logramos comprender cómo funciona nuestro cerebro, podremos diseñar experiencias de aprendizaje que beneficien verdaderamente a los estudiantes, ya que comprenderemos cómo aprenden realmente.

Palabras clave: bilingüismo, inglés, neurodidáctica, neuroeducación, neuroalfabetización, neuromitos, neuroplasticidad, neurociencia.

The Synaptic Classroom: a critical neuroscience framework for English language teaching

Abstract

English Panama's classrooms face significant challenges and need urgent improvement. Even though neuroscience advancements present a reliable solution that offers a wide array of tools to transform English Language Teaching, many teachers continue dragging neuromyths with them into our classrooms, and in most cases, without even realizing it. This article critically analyzes these misconceptions and presents an evidence-based guide with a solid foundation on neuroplasticity, memory, and attention. After analyzing 23 studies identified through academic database searches, following PRISMA requirements, this review identifies critical gaps between research and practice. Results show that more than 60% of teachers endorse unsubstantiated teaching concepts even though there is reliable evidence on multisensorial integration. Empirical data endorse retrieval practices, spaced repetition, and an optimized cognitive load instead of continuing with the traditional massed practice. In addition to this, psychological safety significantly reduces what is known as the "affective filter" (a psychological barrier caused by anxious feelings such as anxiety, fear, or low self-esteem that prevents the processing of comprehensible input by language acquisition mechanisms), thereby improving hippocampal function and retention. Despite these findings, the transition towards neuro-ELT (a method for instructing the English language (ELT) that combines insights from brain science, cognitive studies, and psychological principles to shape educational techniques) demands more than simple workshops; it requires a solid neuroscientific foundation and institutional support. Therefore, planning must prioritize deepening knowledge over quantity, aligning with consolidation and reconsolidation

systems based on brain memory cycles. While neuroscience is no panacea, the integration of these principles fosters neuroplasticity and reduces anxiety. Panama has a chance to be a leader in changing the way we teach in this region if people work together to do research that is specific to this area. Understanding neural mechanisms enables the design of evidence-based learning experiences aligned with how students actually learn.

Keywords: bilingualism, English, neurodidactics, neuroeducation, neuro-literacy, neuromyths, neuroplasticity, neuroscience.

Introduction

Throughout the years, English language teaching in Panama has followed the same methodological trends from grammar-translation to communicative approaches to task-based learning. The assumption that mere procedural compliance equates to methodological progress is often a misconception. We have been designing our curricula without considering the neurological complexity of our diverse student population. We tend to plan lessons, assign homework, and give tests without analyzing whether these practices align with how the brain learns. Neurodidactics has emerged to fill this void, suggesting that instructional design should reflect how the brain processes information. López Arenas et al. (2025) define this discipline as the application of learning from neuroscience in the classroom, to provide instructional practices sensitive to students' cognitive, emotional, and general processing styles.

Current literature reveals substantial gaps between research and practice despite the progress that has been made to date. The latest literature reveals that educators may employ neuro-affirming strategies, but do not have a theoretical literacy to tell what information supports or does not support their marketing myth. According to Yun (2024), increasing neuroscience literacy in educators is no longer optional in the digital age. It is a necessity. We will map specific neural mechanisms into practical classroom practices, critically reviewing the extant literature to suggest a more systematic neuro-ELT methodology.

Databases and search strategy

We systematically selected high-quality, Open Access (OA) articles from reputable journals, electronic databases such as Science Direct, ResearchGate, Elsevier, Frontiers in Psychology/Education/Neuroscience, Google Scholar, PLOS, ERIC, and Canadian Center of Science and Education (CCSE). The following keywords were used: "Neuroscience and English language teaching", "Neuroeducation and EFL" or "ESL", "Brain-based learning" and "second language acquisition", "Neuromyths and language education", "Neuroplasticity and bilingualism", "Cognitive neuroscience

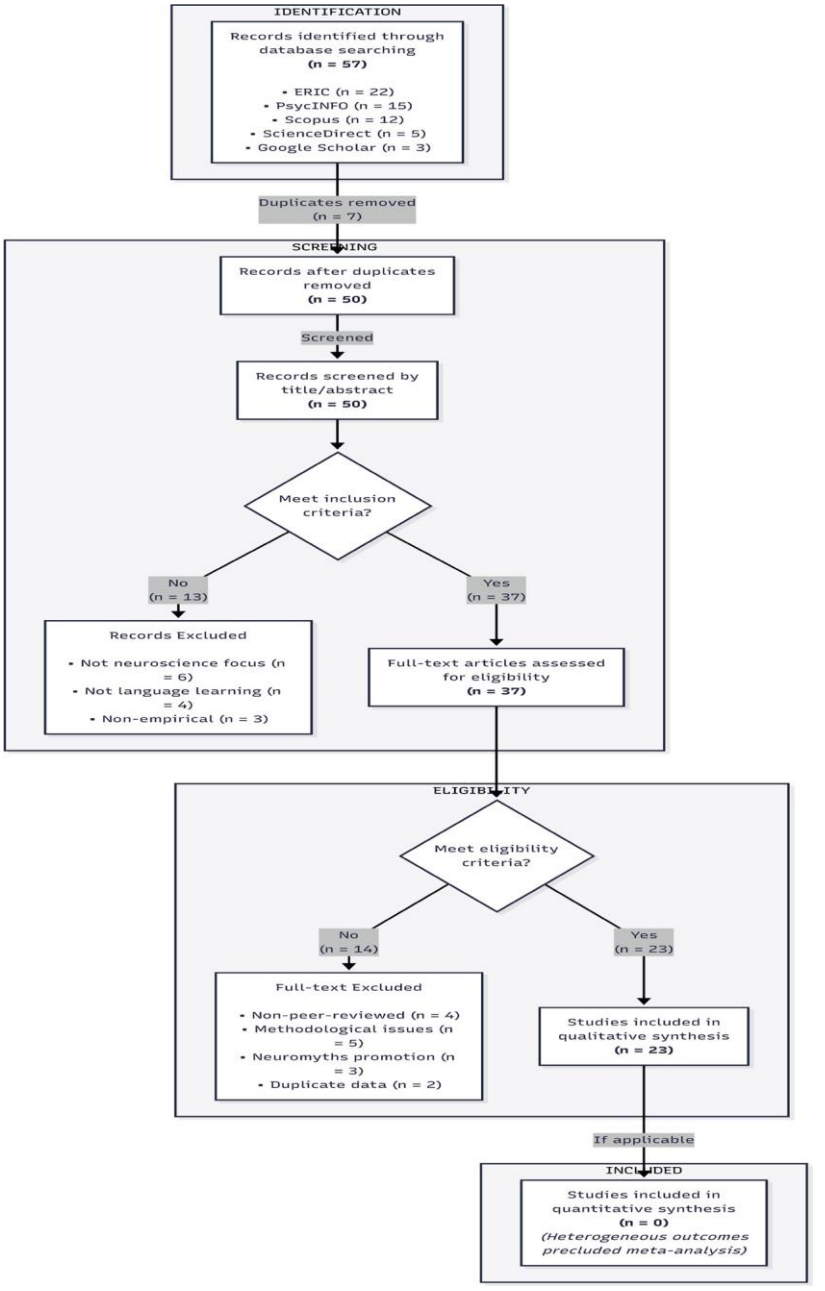
and ELT pedagogy", "Affective filter and neuroscience", "Retrieval practice and language learning".

Studies published between 2020 and 2025 were included to capture current evidence while acknowledging foundational work from the early 2020s. These studies highlight the main aspects and elements related to Neuroscience to be considered when teaching and learning English with the objective of identifying evidence-based methodologies on Neuroscience and Neuroeducation to assess the many situations ESL learners face while going through their language-learning path.

Criteria for inclusion

The initial database search yielded 57 records. Following duplicates removal, 50 records were screened by title and abstract, resulting in 13 excluded records as not meeting the inclusion criteria. Of these, 37 full-text articles were evaluated for eligibility, and 14 articles were removed due to being non-peer-reviewed, exhibiting insufficient methodological rigor, promoting neuromyths without supporting empirical data, or due to data duplication. In the end, the qualitative synthesis included 23 studies, yielding actionable, evidence-based pedagogical implications for the use of neuroscience principles in English language teaching.

Figure 1 Flowchart scientiFic evidence process selection



Note 1. This flow diagram explains the process of selection followed when finding scientific evidence.

Results

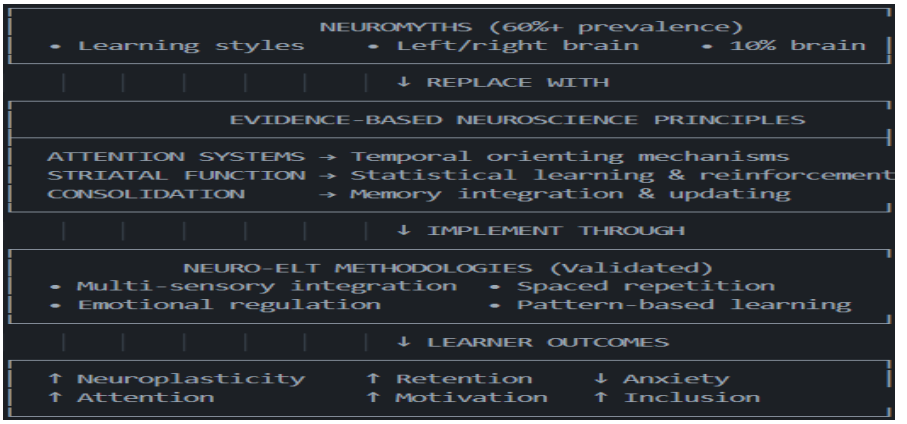
Beyond neuromyths to neuro-ELT

In the current digital era, it is no longer optional; it is imperative to enhance neuroscience literacy among teachers (both EFL and ESL) through targeted professional development programs that assess the effectiveness of teaching and learning (Yun, 2024). García-Peñalvo et al. (2022) found that over 60% of surveyed teachers endorsed at least one neuromyth, such as the belief in fixed learning styles, the left-brain vs. right-brain dichotomy, and the misconception that humans only use a fraction. These beliefs often lead to differentiated instruction based on preferred styles rather than evidence-based multi-sensory integration.

This concept is fundamental because it reflects how the brain naturally integrates information from diverse sensory modalities in our brain and enhances our perception. This multisensory integration allows auditory, kinesthetic, and visual information to be processed simultaneously, leading to significant improvements in retention and comprehension. Not only does this method outperform conventional practice by 20% in vocabulary learning according to Pan (2021), but it also enhances motivation and supports inclusion. It provides critical scaffolding for learners of all needs to help them thrive and enhance their learning through techniques such as tracing, motion, and interactive digital tools.

While López Arenas et al. (2025) provide important qualitative data regarding teacher practices that still perpetuate these neuromyths, they also address Sotelo's (2021) perspective on learning styles. Although the observation related to teachers adapting to student preferences is valid, the neural mechanism is not style-based matching, but rather the universal benefits of multi-sensory engagement (García-Peñalvo et al., 2022). Tokuhama-Espinosa (2024), however, highlights an important distinction: neuroeducation must be scientific and remain true to its principles, unlike commercial brain-based products, which continue to play such a significant role in our classrooms and in society (Ansari & Coch, 2021). Therefore, the development of teaching methodologies must shift from myth-based strategies to practices such as spaced repetition and emotional regulation, which benefit all students regardless of their preferences.

Figure *2 Neuromyths to Neuro-ELT: A Research-Based Framework.*



Note 2. Adapted from the conceptual framework of the Language Learning Research Group, Brainvitge, University of Barcelona (n.d.). Data on neuromyth prevalence from García-Peñalvo et al. (2022); professional development implications from Yun (2024). Copyright 2026 by Yasmín Castillo.

It is necessary to forget about outdated practices and step into the integration of neuroscience strategies with pedagogical practices that allow education to follow a path of effectiveness. Through these practices, language learners will not only develop their neuroplasticity and memory systems, but also improve their retention and attention capacity, emotional intelligence, and reduce their anxiety throughout the learning process.

Hence, the following sections study these benefits in-depth to demonstrate the importance of merging neuroscience and education.

Neuroplasticity and the bilingual brain

This concept challenges the misconception that language learning is restricted only to early childhood. Scientific evidence demonstrates that the brain undergoes structural changes regardless of age, including increased gray matter density in the left inferior parietal cortex, as a response to second language acquisition.

Furthermore, according to the research of Pliatsikas (2020), the Dynamic Restructuring Model (DRM), adults can store more information, which means that they can retain more information in subcortical structures and white matter. This phenomenon occurs during advanced stages of bilingual development and manifests more robustly and clearly in adults than in children. While the developing brain may be intrinsically more plastic due to neural networks still 'under construction,' the DRM model proposes a specific trajectory in which adults demonstrate unique

adaptations based on their accumulated experience.

This distinction is crucial for English Language Teaching (ELT). In her research, Kruhlii et al. (2023) observed that adult learners can manage multiple cognitive processes simultaneously during the language acquisition process, integrating new insights with prior knowledge. However, this ability requires careful support. Li and Zhao (2023) found that late bilinguals adapt to varying learning timelines by enhancing connectivity within their prefrontal-executive networks.

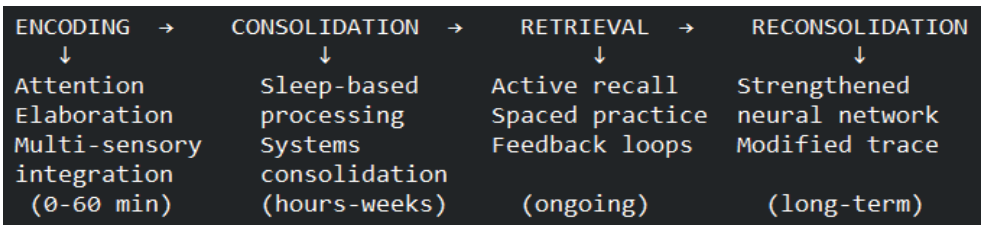
Therefore, educational approaches for adult language learners should leverage their advanced executive functions through metacognitive techniques. This differs from the natural, implicit learning typically observed in children.

Thus, language learning becomes more effective in an environment where adult learning experiences foster a growth mindset and where it is recognized that individuals' learning paths vary. This helps optimize synaptic development and information retention (López Arenas et al.,2025).

Memory systems: encoding, consolidation, and retrieval

Throughout the language learning process, memory formation is not only a one-time event but a whole cycle or a multi-stage process that involves four different stages: encoding, consolidation, and retrieval.

Figure 3 dynamic memory cycle oF language learning.



Encoding constitutes the first crucial step towards a full memory cycle; it is the moment in which the sensory information a human receives, whether visual (through reading text), auditory (listening), or kinesthetic (through movement or by writing), is processed, translated, and temporarily stored in their brains. In this process, the hippocampus plays a central role by integrating diverse elements of information: the phonological form, the semantic meaning, the grammatical properties,

and the context in which a word is specifically used (Guskjolen et al., 2023).

Nevertheless, effective encoding requires much more than passive exposure; it demands time and cognitive effort.

Furthermore, when apprentices can actively make connections or link new vocabulary with existing memory structures through strategies such as semantic mapping or personal association, multiple retrieval pathways significantly strengthen long-term memory and retention.

Following encoding, consolidation converts transient memories into permanent knowledge through two processes: synaptic consolidation (which occurs within hours through protein synthesis) and systems consolidation (which takes place over days and weeks as memories are stored in cortical networks). Most importantly, slow-wave sleep enables the transmission of declarative memories from the hippocampus to the neocortex, yet few studies on language acknowledge this physiological requirement (Rasch & Born, 2024).

After consolidation, retrieval is not just a passive act of accessing stored information; it actively reconstructs memories by reorganizing traces through reconsolidation. This retrieval effect shows that active recall promotes better retention compared to passive recall (Pan, 2021). Neuroimaging supports these behavioral findings: Middleton et al. (2021) discovered that retrieval practice engages the hippocampal-prefrontal networks more extensively than re-reading. Additionally, recent evidence suggests that spaced repetition systems significantly outperform massed practice in vocabulary retention (Chen, 2024), emphasizing the importance of a well-structured temporary distribution in learning.

Working memory works within restricted capacity limits, often cited as approximately four information chunks that require a careful instructional design to prevent cognitive overload (Al-Harbi, 2023). Within this framework, Cognitive Load Theory distinguishes between intrinsic load (material complexity), extraneous load (poor design), and germane load (beneficial schema construction) in these models. Effective ELT reduces extraneous load by using integrated materials (thereby reducing divided attention), manages intrinsic load through scaffolding, and maximizes germane load through purposeful practice and schema automation.

Consequently, from an educational perspective, lesson planning must prioritize strategies that align with cognitive architecture instead of intensive memorization (cramming). This implies implementing low-stakes quizzes to take advantage of the evaluation effect, programming spaced review to combat forgetting, and incorporating sleep-dependent consolidation periods into learning schedules.

Emotion, stress, and the affective filter

Emotional states influence language processing through the affective filter, a psychological barrier in which anxiety, fear, or low self-esteem prevent comprehensible input from being processed by the language acquisition mechanisms. From a neurophysiological perspective, stress activates the amygdala, leading to the release of cortisol, which impairs prefrontal executive function and the consolidation of hippocampal memory (Ansari & Coch, 2021; Tokuhama-Espinosa, 2024). In contrast, psychological safety reduces the affective filter by lowering cortisol levels and increasing dopamine levels, which enhances attention, motivation, and the willingness to communicate.

Recent studies indicate that safe learning environments are the driving force of students' motivation. For example, López Arenas et al. (2025) found that safe environments were among the top factors that motivated the vast majority of students interviewed for a study conducted with them, and that authentic materials (e.g., songs, films) stimulate curiosity through dopamine-driven reward pathways. One key focus for teachers is the need to normalize errors, engage in low-threat activities, and use emotionally energizing materials to manage physiological arousal and facilitate cognitive engagement (Immordino-Yang, 2024; MacIntyre, 2020).

Attention and the Reticular Activating System (RAS)

The reticular activating system (RAS) acts as a neural gatekeeper, filtering millions of sensory stimuli and allowing only novel, relevant, or emotionally significant information to enter conscious processing (Fedorenko et al., 2021). With this biological reality in mind, lessons must begin with attention-grabbing "hooks" and sustain that interest through substantive content that students find personally relevant.

However, digital multitasking significantly impairs learning. Uncapher & Wagner (2024) found that divided attention reduces hippocampal activation and impairs memory consolidation, while chronic multitaskers exhibit reduced gray matter density in the anterior cingulate cortex, a region critical for cognitive function and emotional regulation.

Notably, effective pedagogical practices often align with neurobiological principles, even when teachers lack explicit theoretical knowledge. López Arenas et al. (2025) found that teachers intuitively incorporated movement breaks and sensory-rich materials into their lessons despite having limited theoretical knowledge. Focus blocks organized without digital distractions, Total Physical Response strategies, and gallery walks, for example, are also consistent with the neurobiology of attention (Sato, 2024).

Discussion

Recent literature reviews highlight a paradox in neuro-ELT practices. Teachers act as intuitive neuroscientists, applying techniques without fully understanding why they work. López Arenas et al. (2025) offer useful insights into this intuition, in which emotional factors and authentic materials play a significant role.

Nevertheless, their reliance on self-reported data and the perpetuation of neuromyths, such as the concept of learning styles, undermine the generalizability of their findings. While teachers' perceptions and intuition are valuable, subjective perceptions do not always align with cognitive reality.

In other words, future research should expand beyond interviews to include cognitive pre- and post-tests. This would demonstrate causal relationships between neuro-strategies and proficiency gains.

In addition, theoretical knowledge regarding the use of strategies remains a major gap. González et al. (2022) found that while teachers use neurodidactic tools, they lack proper training. This leaves them vulnerable to commercial products that lack scientific rigor (Ansari and Coch, 2021).

Closing this gap will require institutional support that validates sound judgment and corrects misconceptions. Neuroscience and education must work together to co-develop research questions that have ecological validity (Ansari and Coch, 2021).

Future directions toward ecologically valid research

As Ansari and Coch (2021) emphasize, neuroscience and education must co-develop research questions in a collaborative way to ensure ecological validity. Laboratory studies about memory and attention are often based on experimental and artificial tasks that are highly controlled and cannot be generalized to dynamic and socially complex classroom environments. Addressing this gap will require translational research that respects both neural mechanisms and pedagogical reality.

Therefore, future research in Panama should employ collaborative partnerships between neuroscientists and educators to establish ecological validity, as advocated by Ansari and Coch (2021). In Panama, there should be further research by transdisciplinary teams to ensure findings apply to the local context. To achieve this, it is essential to consider the following recommendations:

1. Through design-based research studies, foster collaborative cycles in which teachers and researchers co-build and implement well-

informed neuroscience interventions in authentic classroom environments.

2. Use mobile neuroimaging (portable EEG, fNIRS) to study and monitor brain activity in life, prioritizing ecological validity over isolated laboratory tasks.
3. Conduct longitudinal designs and implement student monitoring over semesters or years to reflect the more gradual and non-linear nature of language learning instead of relying on one-off assessments.
4. Employ mixed methods combining quantitative measures of proficiency and qualitative analysis of teacher practice and student experience.
5. Conduct investigations focused on context, exploring how the philosophy of neuroscience interacts with the specific linguistic character of Panama (for example, Spanish-English bilingualism, indigenous languages, creole varieties).

This research would generate locally applicable knowledge that could add to international knowledge about educational neuroscience.

Conclusions and suggestions for future research

Integrating neuroscience into English as a Foreign Language (EFL) teaching is an exciting opportunity to bring about positive change in learning outcomes in Panama. This review has shown that principles of neurobiology relevant to memory, attention, and emotion form a strong basis for pedagogical practice, overcoming the neuromyths hampering effectiveness within education. However, the gap between educational neuroscience research and classroom practice in Panama is prominent and multidimensional.

Teacher education programs must include fundamental educational neuroscience in which teachers learn to differentiate between empirically based principles and commodified neuromyths. It will take a shift from one-off workshops to extended professional learning communities.

English language curricula should also explicitly integrate principles such as spaced retrieval practice, cognitive load management, and development of emotionally secure contexts. This requires reducing content coverage in favor of learning depth.

Globalization and technological change are altering this; however,

evidence suggests these shifts may lead to increased distractibility rather than a categorical reduction in attention spans (Uncapher & Wagner, 2024). Consequently, educational institutions need to establish technology policies that balance digital integration with periods of deep, distraction-free focus. Furthermore, it is imperative to ensure that teachers have sufficient planning time to enable evidence-based instructional redesign

Finally, language teachers and institutions must prioritize conducting research that bridges neuroscience and pedagogical practice. Panama requires research that is contextually relevant to examine how neuroscientific principles apply in the educational context, considering cultural, linguistic, and socioeconomic factors. Collaboration between universities, schools, policymakers, and other stakeholders can generate evidence useful to decision-makers.

Educational neuroscience does not offer universal solutions. Neuroscientific principles must be applied to different contexts, considering variables such as available resources, class sizes, teacher skills, and student characteristics. Furthermore, neuroscience contributes to—but does not replace—pedagogical expertise, subject-specific knowledge, and an understanding of classroom dynamics. Neuroscience is no panacea. Yet it is a powerful toolkit for effective teaching.

When teachers understand the brain's learning mechanisms, they can create learning experiences that respect cognitive architecture, positively regulate emotions, and sustain student engagement. This approach will not only improve English proficiency but also foster motivation, confidence, and the cognitive and socio-emotional skills essential for life.

Panama is well-positioned to take the lead in this area by integrating neuroscience with English language education. Seizing this opportunity will require vision, dedication, and collective action from all stakeholders in educational organizations. Panamanian students possess neuroplastic, emotionally responsive brains capable of sustained attention, warranting evidence-based educational approaches.

Disclosure Statement

There was no conflict of interest reported during research.

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