

# Teaching English to the Rhythm of the Brain

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## Resum

Ensenyar i aprendre idiomes de manera eficient esdevé cada cop més important, especialment quan es tracta de l'idioma anglès. Els sistemes educatius han de ser capaços de dotar els estudiants de les eines i habilitats necessàries per enfrontar-se a aquest món. Tot i això, encara hi ha marge de millora per aconseguir aquest propòsit. Aquest article cerca contribuir a la millora del procés d'ensenyament-aprenentatge de l'anglès a partir dels descobriments de les neurociències. És una revisió bibliogràfica que proporciona troballes basades en la neurociència per ajudar els professors a facilitar l'aprenentatge de llengües estrangeres. Els avenços en neurotecnologia han permès als neurocientífics observar directament el funcionament del cervell humà. En aquest context se situa el camp interdisciplinari de la neuroeducació. S'especialitza a servir l'educació en proporcionar evidència cerebral rellevant. Aquest estudi va trobar que els mestres han d'estimular la motivació, l'atenció, les emocions i la memòria per ajudar els estudiants a processar i aprendre anglès. Aquest estudi es contextualitza a l'ensenyament d'estudiantat de Secundària. Amb els adolescents, els mestres han de considerar la importància de reduir l'estrès, promoure el sistema de recompenses, utilitzar la varietat a l'ensenyament, enfortir la memòria de treball i fomentar la interacció social, així com una mentalitat de creixement.

En observar el llenguatge al cervell, sembla que ambdós hemisferis estan involucrats en el procés del llenguatge, cosa que sembla emfatitzar la importància de proporcionar un entorn d'aprenentatge multimodal ric. A més, tant la memòria declarativa com la processal són sistemes de memòria subjacents a l'adquisició del llenguatge. Tot i això, els adolescents tenen una memòria declarativa més forta. Implica que els professors d'idiomes han d'apel·lar aquests darrers alhora que permeten el desenvolupament de la memòria procedimental. A la llum de les troballes, aquest estudi produeix una guia que exemplifica la incorporació dels principis de la neurociència dins una lliçó d'anglès estàndard. Porta els mestres a considerar les troballes de la neurociència i operar intencionalment; i crear un entorn d'aprenentatge on els docents instrueixin al ritme del cervell i optimitzin les habilitats de l'alumnat.

**Paraules clau:** neuroeducació; neurociència educativa; neurociència cognitiva; idioma; anglès com a segon idioma; memòria; procés d'ensenyament-aprenentatge.

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### Abstract

Efficiently teaching and learning languages becomes increasingly important especially when it comes to the English language. Education systems should be able to equip students with adequate tools and skills required to face this world. However, they still have some room for improvement to achieve that purpose. This article seeks to contribute to the enhancement of the teaching-learning process of English by considering neuroscience discoveries. It is a bibliographic review providing neuroscience-based findings to help teachers facilitate the learning of foreign languages. Advances in neurotechnology have allowed neuroscientists to directly observe the functioning of the human brain. In this context lies the interdisciplinary field of neuroeducation. It specialises in serving education by providing relevant brain evidence. This study found that teachers should stimulate motivation, attention, emotions, and memory to help their students process and learn English. The present study concerns the teaching of high school students. With adolescents, teachers should consider the importance of reducing stress, promoting the reward system, using variety in their teaching, strengthening working memory, and fostering social interaction as well as a growth mindset.

Looking at language in the brain, it appears that both hemispheres are involved in the language process which seems to stress the importance of providing a rich multimodal learning environment. Besides, both declarative and procedural memory are memory systems underlying language acquisition. However, adolescents have a stronger declarative memory. It entails that language teachers should appeal to the latter while allowing for the development of the procedural memory. In the light of the findings, this study produces a guide which exemplifies the incorporation of neuroscience principles within a standard English lesson. It leads teachers to consider neuroscience findings and operate intentionally. Creating a learning environment where teachers instruct at the rhythm of the brain and students' skills are optimised.

*Keywords:* neuroeducation; educational neuroscience; cognitive neuroscience; language; English as a second language; memory; teaching-learning process.

### Resumen

Enseñar y aprender idiomas de manera eficiente se vuelve cada vez más importante, especialmente cuando se trata del idioma inglés. Los sistemas educativos deben ser capaces de dotar a los estudiantes de las herramientas y habilidades necesarias para enfrentarse a este mundo. Sin embargo, todavía tienen margen de mejora para lograr ese propósito. Este artículo busca contribuir a la mejora del proceso de enseñanza-aprendizaje del inglés a partir de los descubrimientos de las neurociencias. Es una revisión bibliográfica que proporciona hallazgos basados en la neurociencia para ayudar a los profesores a facilitar el aprendizaje de lenguas extranjeras. Los avances en neurotecnología han permitido a los neurocientíficos observar directamente el funcionamiento del cerebro humano. En este contexto se ubica el campo interdisciplinario de la neuroeducación. Se especializa en servir a la educación al proporcionar evidencia cerebral relevante. Este estudio encontró que los maestros deben estimular la motivación, la atención, las emociones y la memoria para ayudar a sus estudiantes a procesar y aprender inglés. El presente estudio se contextualiza en la enseñanza de estudiantes de Secundaria. Con los adolescentes, los maestros deben considerar la importancia

de reducir el estrés, promover el sistema de recompensas, utilizar la variedad en su enseñanza, fortalecer la memoria de trabajo y fomentar la interacción social, así como una mentalidad de crecimiento.

Al observar el lenguaje en el cerebro, parece que ambos hemisferios están involucrados en el proceso del lenguaje, lo que parece enfatizar la importancia de proporcionar un entorno de aprendizaje multimodal rico. Además, tanto la memoria declarativa como la procesal son sistemas de memoria que subyacen a la adquisición del lenguaje. Sin embargo, los adolescentes tienen una memoria declarativa más fuerte. Implica que los profesores de idiomas deben apelar a estos últimos al tiempo que permiten el desarrollo de la memoria procedimental. A la luz de los hallazgos, este estudio produce una guía que ejemplifica la incorporación de los principios de la neurociencia dentro de una lección de inglés estándar. Lleva a los maestros a considerar los hallazgos de la neurociencia y operar intencionalmente; y crear un entorno de aprendizaje donde los profesores instruyan al ritmo del cerebro y se optimicen las habilidades de los estudiantes.

*Palabras claves:* neuroeducación; neurociencia educativa; neurociencia cognitiva; idioma; inglés como segundo idioma; memoria; proceso de enseñanza-aprendizaje.

## Introduction

Knowing a second language in particular English is increasingly becoming a standard requirement. However, many students are leaving school without having good English language skills. Even though it forms part of the curriculum, the level of English is minimal, particularly in Spain. The EF English Proficiency Index for Schools (EF EPI-s), which evaluates the English skills of full-time students between 13 and 22, reveals that the level has not improved in almost a decade<sup>1</sup>. The reason might be economic or cultural. Though countries in a similar situation to Spain show a better score<sup>2</sup>. One root of the issue might be in the teaching-learning process of English.

It is important that the education system as well as educational institutions achieve their objective of efficiently teaching English. They need to be able to prepare their students to face the demands of a globalised world. Especially in the case of high school students who are about to enter adulthood and leave school to pursue higher education and/or a job. Adolescents' brain is still maturing, and they sometimes struggle to properly regulate their emotions and behaviour. The teaching-learning process must respond to their needs by helping, motivating, and encouraging them to learn English.

A negative learning experience not only can affect present learning processes, but also future ones. It can lead students to avoid exposing themselves to a similar experience. That is, in this case, to refrain from learning English or another foreign language. These students then become young adults with frustrations and mental blocks against learning languages. However, if the experience is positive, it can open the doors for successful and rewarding language learning events.

The human being is wired to learn. We are gifted with a complex, fascinating, and powerful organ: the brain. It allows us to learn throughout our whole life. It gives the capacity to succeed in accomplishing complex challenges such as learning a second language. However, its potential is triggered when respecting its functioning, its rhythm. Therefore, in Spain, language teachers may need to teach English while respecting the way the brain learns.

Consequently, knowledge about brain function becomes crucial. Understanding how the brain learns allows one to know both what to avoid and what to stimulate to generate a fruitful teaching-learning process. Teachers have a lot of influence on their students' brains. They are at the forefront of the teaching system directly dealing with and shaping students' brains. A need arises for language teach-

ers to be aware of this influence, as well as to know the tools they may use to boost the brain's potential.

Understanding how the brain learns leads us to neuroscience. Advancements in neurotechnology have allowed scientists to explore the brain and its functioning. More particularly, they are now able to observe how cognitive functions, such as language and learning, occur in the brain. They can detect what affects them. These contributions can greatly inform teachers about what to take into account to facilitate the learning of their students.

However, the connection between neuroscience findings and educational practice is not always clear and easily made. Recently, the emerging field of neuroscience has attracted lots of attention. There is a large amount of information available on the matter. Presently, it may still not be obvious what language teachers can take out of the broad field of neuroscience.

The goal is not to suppress traditional teaching, but to optimise it. Neuroscience findings may shed light on good practices while pointing out what can be altered. By understanding relevant facts about the brain, teachers would not only efficiently teach languages. But they would also respect the individual through the respect of their brain functioning. Teachers would teach to the rhythm of the brain. They would contribute to the shaping of young adults. The latter would be ready to face the realities of the world, equipped with appropriate tools to keep on learning and blossoming in areas of their lives beyond their language learning journey.

For this reason, this article aims to explore how neuroscience can help teachers foster the learning of English as a foreign language in high school students. It will first explore the contribution of neuroscience to education. Based on how the brain learns, it will characterise the aspects that should be stimulated to improve students learning outcomes. Then, it will stress important aspects to consider in the adolescent brain. In addition, it will look at second language acquisition from a neuroscience perspective. Highlighting the main brain areas involved in language processing. Followed by studying the memory mechanisms underlying second language acquisition. In the light of this finding, it will provide for neuro-based strategies to teach languages, as well as a guide exemplifying how teachers can incorporate neuroscience findings within a typical English class.

## Materials and methods

This article is based on a thesis conducted within the master of neuroeducation and skills optimisation programme from the Instituto Superior de Estudios Psicológicos (ISEP, Barcelona). To write the thesis, a bibliographic review was conducted. The literature was based on academic and scientific sources published between 2016 and 2021. The sources are multidisciplinary and come from the field of neuroscience, cognitive neuroscience, psychology, pedagogy as well as linguistics. English was the key language of the research, but sources in French and Spanish were also consulted.

This article presents neuro-based approaches and strategies which language teachers can use to trigger the potential of the brain. It was done based on the consulted literature associating neuroscience and the teaching of languages. This article also provides an excerpt of the didactic guide elaborated within the master thesis. This guide aims to exemplify a neuroscientific approach to English lesson planning. The guide has two parts. The first part lays out some principles and basics of neuroscience for the education of foreign languages. It operates as a teaching-learning framework. This part was developed from sources presenting the contribution of neuroscience to both education and the teaching of a second language. The second part consists of the elaboration of actual language teaching sessions. It is an example of an English course incorporating neuroscience-based principles and strategies. It was designed relying on identified neuroscience-based strategies and approaches to teach a second language.

## Results

### Neuroscience at the service of education

Recent developments in neurotechnology have allowed researchers to observe the brain's function. Given these advances, neuroscientists were able to discover more about how the brain learns. "Educational neuroscience", also labelled as "Neuroeducation" or "Mind, Brain, and Education science"<sup>3,4</sup>, is an emerging field that seeks to study how neuroscience findings can shape education<sup>5</sup>. It aims to translate findings regarding the neurobiological process of learning into educational practices<sup>6</sup>. Neuroscience

research has revealed that the brain has a lot of potential. Though, its natural biological identity is shaped into a unique brain when interacting with its environment<sup>7</sup>. Educational neuroscience seeks to study which learning environment allows the brain to be in its optimal state to obtain a fruitful learning process. As a result, it would reach its objective to improve learning outcomes by providing tools and approaches that both teachers and students can use to improve the learning process. It not only studies how to enhance cognitive functions but also looks at other factors influencing learning. They include sport, sleep, stress, and diet. However, this article will focus on factors which teachers may influence.

As illustrated in **figure 1**, neuroeducation is an interdisciplinary approach combining neuroscience, education/pedagogy, and psychology. It draws from neural, cognitive, and behavioural mechanisms<sup>4</sup>.

Education has long been enriched by psychology. Thomas et al. asked what else neuroscience can bring to the field of education. He mentioned that psychology focuses on behaviour while neuroscience studies the “brain mechanisms underlying behaviour”<sup>6,p.2</sup>. Neuroscience allows delving further into the mind, observing the brain and its nervous system. It can directly contribute to education. Informing about the brain which in its optimal state leads to improved learning outcomes. It brings a holistic approach to the understanding of the brain and learning. It can study all the internal and external factors influencing it. It studies how to have a healthy brain, how to improve it, how to optimise it, and how to compensate for weaknesses and disabilities. A healthy brain is the fundamental start of

all successful learning journeys. By the same token, neuroeducation helps professionals understand and respond better to the needs of students with learning disabilities.

Neuroeducation is a new approach to education. It equips relevant educational actors including teachers and students with an understanding of the brain. It sheds light on the efficiency or inefficiency of certain methods. Consequently, teachers act knowingly, and students are empowered and transformed into actors of their learning. As we will see throughout this article, neuroscience calls for an approach centred on students’ well-being and involvement.

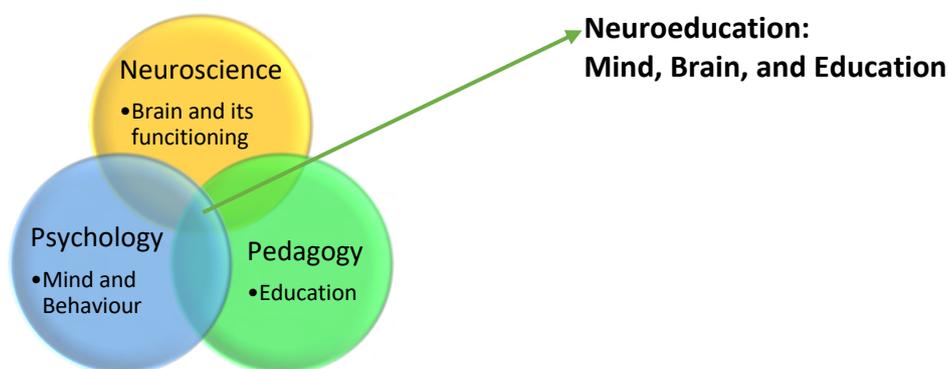
### How the brain learns

Acquiring a language means learning a language. Learning is a neurobiological process. Therefore, before looking at language acquisition in the brain. This section will highlight important elements of the brain learning process, to identify what language teachers should foster to help their students learn.

### Motivation to learn

Motivation is an essential element of learning. Simply put, it is what drives us to act. It is affected by “a complex set of intertwined social and biological factors”<sup>8,p.1</sup>. It involves the frontal lobe (**figure 2**). It is based on life experiences. Repeated experiences generate the release of chemicals to regions connecting the action to emotions, memory, and the feeling we had while experiencing it.

Motivation occurs when we are motivated to reproduce what caused a pleasant feeling. A chemical involved in this neural circuit is dopamine. The



**Figure 1.** Mind, Brain and Education. Neuroeducation is an interdisciplinary field. Adapted from “Knowledge Transformation and Distance Learning for Secondary Education Students. The Role of Educational Neuroscience,” by Doukakis S, Alexopoulos, E. C. 2020, SEEDA-CECNSM. Copyright 2020 by IEEE.

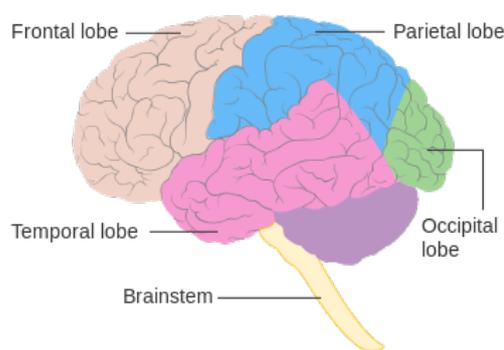
National Scientific Council on the Developing Child points out different types of motivations, namely the “approach motivation” and the “avoid motivation”<sup>8</sup>. The former is linked to reward expectation. Both the anticipation of an experience and the experience in itself trigger the release of dopamine. The latter leads to withdrawal from the experience. It is connected to fear and disgust. The amygdala plays a role in this process. Experiences can teach “avoid motivation”. This is so when the brain indicates to stay away from a particular activity based on the correct or incorrect prediction that engaging in that activity may lead to a threatening situation. It implies that language teachers should intentionally promote their students’ motivation by creating positive learning experiences; giving constructive feedback; clearly outlining objectives relevant to the students, and helping students to find intrinsic motivation by reflecting on what they can take out of the learning.

### Focus on attention

Attention also plays a crucial role in learning. It allows the brain to process stimuli, thoughts, and actions. It prioritises some inputs and disregards others. Attention is the neural mechanism underlying the selection of relevant information<sup>9,10</sup>. Voluntary attention can enhance the accuracy of memory. Conversely, lack of attention results in loss of accuracy and possibly loss of the item altogether. Brain areas involved in attention are the parietal, temporal, and front lobes (**figure 2**). The neural areas playing a role in attention are linked to the brain area implicated in sensory processing<sup>9,10</sup>. Attention is affected by internal and external factors such as internal goals, lighting, teacher’s styles, intonation, noise etc. Recent research provides the following strategies to capture students’ attention: taking breaks; providing new information in a brief, precise and clear way to ease the processing; presenting the content with sensorial contrast; providing new and relevant stimulus perhaps with an element of surprise. Emotions also capture attention. However, it is important to avoid cultivating counter-productive emotions such as anxiety<sup>9</sup>.

### Emotions and learning

Emotions are of high importance in a learning environment<sup>6</sup>. Emotional information generates the activation of several areas of the brain (**figures 2 and 3**). Including the amygdala, the orbital prefrontal cortex,

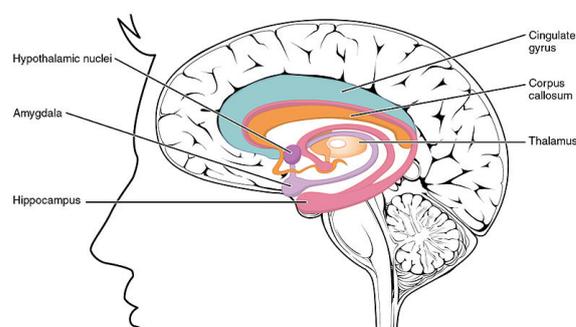


**Figure 2.** Diagram showing the lobes of the brain. Cancer Research UK, CC BY-SA 4.0 via Wikimedia Commons.

and the dorsolateral prefrontal cortex (frontal lobe) which are associated with memory and emotion<sup>11</sup>.

The generation of emotions indicates more mental and brain activities. Emotional memories are stronger than neutral ones. The process of emotional data strengthens long-term memory via the synergy between the amygdala and the hippocampus. The amygdala boosts the process of encoding and consolidating emotional data in the hippocampus (**figure 2**)<sup>11</sup>.

Both the learning environment and the content can significantly be impacted by emotional stimuli. Feelings towards a learning experience are significant. Positive emotions trigger the release of endorphins, which can generate pleasurable and successful learning. However, cortisol is released when negative feelings such as undue stress are present. It causes a defensive reaction like fight or flight. Emotions can be reflected in the taught content. Students will



**Figure 3.** A diagram of the brain showing the limbic system which is involved in emotions and memory. OpenStax College, CC BY 3.0 via Wikimedia Commons.

probably better remember content involving positive emotions<sup>5</sup>. A way for teachers to manage students' emotions is to start with handling theirs first. In fact, the most basic way of learning is through imitation. This is connected to the notion of mirror neurons. They are activated both when individuals execute an action and when they observe another person doing it. It is not only a learning mechanism but a way to deduce other people's emotions, intentions, and feelings<sup>12</sup>. Considering that language learners often feel vulnerable and lack confidence, language teachers need to have the right intentions, believe in their students, and control their emotions. In such a way that it will trigger emotions in their students that will enhance their learning experience.

Memory per se can also be strengthened to help students learn English, as it will be emphasized in the next sections.

### *What about the adolescent's brain?*

This research concerns teachers helping high school students, otherwise said, adolescents, to learn. To teach to the rhythm of the brain, it is important to adapt to the target learner's neurobiological development. Teenagers are not always an easy group to deal with. However, understanding a little bit about their brain may help teachers to manage and assist them better.

Adolescents go through important changes in their brains. Besides, their prefrontal cortex is still under development until completion in the mid-twenties. The prefrontal cortex (see frontal lobe, **figure 2**) oversees executive functions such as attention, planning, rationalisation, regulation of emotions, and comprehending the repercussions of one's actions. During stressful events, the impulsivity in the fully formed limbic systems (**figure 3**) takes over "the reflective prefrontal cortex system"<sup>13 p.6490</sup>. The influence of the rationalisation coming from the prefrontal cortex is thus weakened.

Besides, factors such as stress, excessive information, and content lacking connection with previous learning can cause "cognitive overload". The latter diminishes the capacity of the working memory (WM) which can lead to the weakening and or the shutdown of the prefrontal cortex functioning<sup>13</sup>.

The WM has a limited amount of space. It is where the information is built, processed, and worked on. The WM can only manage a limited number of ele-

ments at the time, 5 to 9 items for adolescents. Recent studies even reduced the capacity of their WM down to 3 or 4 items at the time<sup>5</sup>. Though in reality, it depends on the person, the input, the context, and the precise age. The prefrontal cortex contributes to the working memory<sup>14</sup>. It is significant during the process of information. It manages functions such as planning and comprehension<sup>13</sup>. The WM is a temporal memory. However, motivation can increase the time information is processed, and our attention paid to it<sup>5</sup>.

Peers, exploration, and performance feedback affect adolescents' motivation. Teenagers go from a life highly influenced by their parents to one shaped by their peers. Relationships with peers become increasingly more important, deeper, and more rewarding. They tend to have a higher "neural response to social acceptance and rejection than adults"<sup>8,p.5</sup>. Social interactions trigger the brain area in charge of releasing dopamine.

Adolescents' "sensitivity to social reward" may on one hand direct them to engage in "risk-taking" and "self-oriented acts", and on the other hand strengthen exploratory learning and the capacity to "adapt to different social contexts and cultures"<sup>8,p.5</sup>. Personal learning exploration together with productive feedback can motivate and help adolescents to learn better.

To support the learning of adolescents, it is important to reduce the level of stress, develop a reward system content, and provide for a variety of ways to present the content<sup>13,15</sup>. It is also necessary to foster social interactions and exploratory learning, provide positive and constructive feedback, promote a growth mindset, and praise the process rather than the performance<sup>8</sup>. Activities to enhance the working memory are likewise beneficial. Such activities can include "strategy building games, visual memory games, chess, and picking out relevant information from random texts"<sup>13 p.6492</sup>.

## **Neuroscience at the service of language**

### *Neuroplasticity and Critical Period Hypothesis*

This section will look more specifically at the contribution of neuroscience to the learning of a second language. It will start by discussing the concept of the Critical Period Hypothesis and neuroplasticity to address older children and adults' capacity to learn.

Then, it will mention key brain parts involved in language and will pursue with the memory systems underlying language acquisition.

It is presumed that (younger) children can easily unconsciously learn a second language and acquire the same level of language skills and pronunciation as native speakers. A question arises as to whether older children and adults may as well acquire high proficiency in a language. This leads to the Critical Period Hypothesis (CPH).

It refers to the period within which a person can learn a language. Early childhood has been considered to fall within such a period. This is due to children greater brain's plasticity. Babakulova refers to different theories about the CPH however there seems to be no consensus as to the extension of such period and what it exactly entails<sup>16</sup>.

Though, one element that is not questioned is the brain's plasticity. Out of all the organs, only the brain is able to learn new information and teach itself. It refers to the brain's capacity to change and adapt to the environment and experiences lived by the individual. It indicates that learning can occur until old age. We could thus include the learning of languages. In addition, Babakulova identified findings that adults can attend a level of pronunciation and grammar like native speakers. Moreover, older learners benefit from certain advantages. They can intentionally trigger motivation as well as be exposed to the appropriate learning environment necessary to learn a language. Having developed the first language is also an advantage on which older children and adults can rely on to acquire a second language<sup>16</sup>. Making associations and connections is a significant way to learn. This implies that teachers and students alike should believe that when provided with adequate stimuli, older children and adolescents may as well successfully learn a language.

### Language in the brain

Language learning is performed by the brain. This section will mention the main regions of the brain involved in language. Since languages must be learned and memorised, it will proceed by explaining which memory systems cover language acquisition.

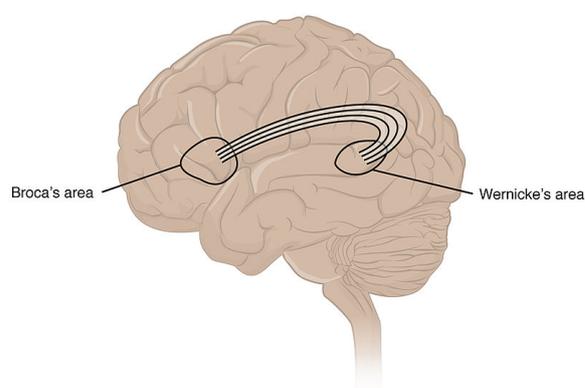
### Brain parts involved in language

Research have maintained that language processing is dominant in the **left hemisphere** of the cerebrum.

An important area of the brain when it comes to language is the **Broca area** located in the left frontal lobe (**figure 4**). Damage in this area results in difficulty producing the sounds required for the speech. Understanding remains but making the words becomes a problem. Another area located in the left hemisphere is **Wernicke's area** positioned at the back of the temporal lobe (**figure 4**). Damage to this area causes patients to produce a sound that is not intelligible, and to lack understanding of language<sup>17,18</sup>. It was found that first language and second language are "spatially separated in Broca's area" which is a region in charge of the movement of the palate, tongue, and mouth<sup>17,p.124</sup>. Conversely, very minor separation was observed within the Wernicke area responsible for the understanding of language.

Even though language is significantly processed in the left hemisphere, recent studies found that the right hemisphere might have a major role in assisting learners to identify new sounds at the initial stage of learning<sup>19</sup>. Furthermore, it contributes to intonation, gesture, automatic speech, and a non-analytical approach to language<sup>20</sup>. Thus, both hemispheres are necessary for language processing, which directs language teachers to opt for the creation of a holistic and multimodal teaching-learning process.

The **cerebellum** is another area involved in language. Previously, it was thought to only play a role in movement. But now it is known to also take part in cognition such as language and memory. Other important regions are the **basal ganglia**, the **hippocampus**, and some areas in the **medial temporal lobe**<sup>21</sup>.



**Figure 4.** Broca's area and Wernicke's area circled in the left hemisphere of the brain. OpenStax College, CC BY 3.0 via Wikimedia Commons.

### Memory system underlying language acquisition

Understanding the memory systems supporting language learning is important. It allows teachers to comprehend the evolution in language acquisition<sup>22</sup>. In this way, they can better support students along their language journey.

Based on the principle of co-optation and the fact that languages are learned, Ullman asserts that the declarative memory and the procedural memory should be involved in language. It refers to this theory as the **declarative/procedural model**<sup>21</sup>. To grasp better the model, declarative memory and procedural memory are going to be described.

**Declarative memory** is knowing “what”. It is the memory of events and facts<sup>14</sup>. It involves the hippocampus and other medial temporal lobe structures. Together they underlie the learning and consolidation of information. Over the longer term, that information seems to rely more on the neocortex, particularly in the temporal lobes. Frontal regions may also be involved in the codification of new memories and their later recall. The neurotransmitter acetylcholine plays a role (the hormone estrogen). Declarative memory is specialised “for learning arbitrary pieces of information and their associations”<sup>21,p.131</sup>. It is flexible. It can learn more than semantic and episodic elements. Learning happens fast in this system. One exposure to the information can be enough to remember it. Explicit memory can only be learned under the declarative memory. Though this system supports both explicit and implicit knowledge.

The strength of declarative memory depends on the age. It appears to expand during childhood and stabilise throughout adolescence and early adulthood to later weaken. This means that “an older child, adolescent, or young adult tends to be better at learning in this system than a young child”<sup>21,p.132</sup>. Other factors influencing declarative memory are sleep and exercising which can respectively help with memory consolidation and reinforcement. Sex can also affect it. Females tend to have a more enhanced declarative memory than males, owing to women’s higher estrogen levels. Left-handers may benefit from an enhanced declarative memory.

**Procedural memory** is knowing “how”. It relates to the process and learning of motor and cognitive skills. It is based in the basal ganglia and frontal cortex circuits<sup>14</sup>. The former is important for learning new information, particularly during the early phase

and subsequent consolidation. The latter is more for processing automatised routines. It might serve for learning to predict, particularly if it is based on fast feedback. If the prediction is quickly corrected, that results in learning in procedural memory. The Neurotransmitter dopamine, on which the reward/feedback learning relies, is involved. Contrary to declarative memory, learning is gradual. Though the learning eventually becomes reliable and automatised. Retention is strong. One does not forget how to bike. Knowledge is solely implicit. While older children, adolescents and young adults would rely more on declarative memory, younger children tend to depend more on procedural memory.

Ullman’s model claims that the declarative/procedural model should work with language in the same way that it functions in other areas. On this basis, some predictions can be made<sup>21</sup>.

The characteristics of the declarative and procedural memory applied to second language acquisition will be presented in **tables 1 and 2** comparatively to further understand their differences and connections.

Yusuf argues that procedural memory, underpinning implicit memory, is better suited to learning languages<sup>23</sup>. Stipulating that implicit learning is important to achieve language automaticity and to strengthen language proficiency. Implicit learning refers to the brain’s capacity to learn information without explicitly paying attention to it. Since one memory system may block the other, Yusuf gives preference to implicitly learning languages, mimicking the way the first language is learned<sup>23</sup>. Likewise, Zhang, stipulates that unconscious learning is the most efficient manner to learn languages<sup>24</sup>. Though, he recognises the importance and role of conscious learning. Implicit memory can be developed using language structures while focusing on the meaning rather than the form. Another way to do it is through practice and repetition due to the strengthening of synapses in basal ganglia through “repetitive synaptic density” resulting in increased learning<sup>23,p.27</sup>.

Given that older children, adolescents, and adults depend more on declarative memory but eventually have their language rely on procedural memory. It seems relevant to enhance both the declarative and procedural memory to help high school students learn English. Taking advantage of and strengthening their declarative memory while developing their

**Table 1.** Characteristics of the declarative and procedural memory applied to language acquisition

Declarative memory	Procedural memory
Declarative memory is mainly important for lexical memory since it is significant for “learning arbitrary pieces of information and associating them” <sup>21,p.134</sup> . It implies that it serves for learning words, irregulars, and components such as idioms and proverbs.	Procedural memory is significant for sequences and categories such as “grammatical categories” and “speech-sound categories”. It is important for syntax, morphology, and phonology.
Both memories overlap. Thanks to declarative memory’s flexibility, it can also learn “speech-sound category” as well as rule-governed forms and grammatical rules when learned in chunks. Though, it may not be the ideal memory system to support such learning and may lead to complications when seeking to acquire a second language.	
Vocabulary learning via declarative memory may influence where grammar is processed. If grammar relies on procedural memory, it can be refrained by slow access to vocabulary which eventually may lead the learner to rely on declarative memory.	When there is a transfer of grammar (that is when one native language can be relied on to understand the target language), it can be processed under procedural memory provided that lexical retrieval is fast enough.
Language is first learned under this system then progressively and parallelly learned in the procedural memory.	The process of a language eventually becomes rooted under the procedural memory of both younger and older children as well as adults. Though the process is slower for the latter.

Note. Created by the author based on Ullman’s declarative/procedural model

**Table 2.** Factors that enhance each memory

Declarative memory	Procedural memory
Explicit teaching Paying attention to certain aspects of the language Slower feedback	Absence of explicit teaching Not paying attention to aspects of the language Faster feedback Practising higher complexity of rules and patterns More exposure to the target language (e.g., immersion) Task-based learning

Learning in declarative memory and procedural memory can be enhanced through spaced presentation, retrieval practice and exercises.

Note. Created by the author based on Ullman’s declarative/procedural model

procedural memory. Kwedju also emphasises the necessity to stimulate both memory systems in the learning process of older children<sup>25</sup>.

Implications will be mentioned in the following sections that provide tools that English teachers can use to facilitate the learning of their students.

### *Neuroscience-based approaches and strategies to help students learn English*

This section is based on research seeking to apply neuroscience principles to the teaching of a second language. It will provide concrete approaches and strategies that language teachers can use to trigger the potential of the brain. The approaches are presented separately for practicality. Nonetheless, they are interconnected and overlap. This section will start by presenting general neuro-based principles

applied to language teaching. Then it will put forward teaching frameworks in which they can be applied. It will continue by providing strategies specific to language improvement.

- **Being aware of the neurocognitive development**  
Adapting and preparing the lesson according to the target students’ neurocognitive development will help to optimise their learning of English. It also implies the importance to get to know the students and when possible, devoting time to each student<sup>22,26</sup>.
- **Waking up curiosity**  
Promoting curiosity allows catching students’ attention. Curiosity can be fostered by applying the strategies below<sup>27</sup>.
- **Using the power of emotion**  
Taking emotions into account implies that teachers

need to create a safe learning environment allowing for the emotional well-being of their students. Using humour, reducing stress, and avoiding rude and authoritarian manners. Teachers may do so by starting with themselves and transferring positive emotions to students thanks to mirror neurons. They need to believe in their students and have high expectancies. Paying attention to boosting their self-confidence. It also directs teachers to provide content constructively appealing to students' emotions. In this way, emotions will generate attention and attention will lead to learning<sup>17,18,22,26,28,29</sup>.

- **Using stories**

This strategy is linked to the previous one. Stories are a powerful way to bring emotions to education. They enhance retention. They generate curiosity and interest. Studying vocabulary within a story helps to memorise it better. Stories are powerful because they can release dopamine, cortisol, and oxytocin respectively associated with reward/drive, distress/focus, and bonding. It triggers focus, attention, and sympathy. Stories bring meaning and relevancy to content. It also gives room for other activities including group discussions, debate, and reflection but also listening and reading activities<sup>27,30</sup>.

- **Using games**

Similarly, games foster the creation of a comfortable learning environment. It helps to make use of emotions within the learning. It triggers participation and social interaction. It allows for practicing communication skills. It is flexible and leaves room for creativity<sup>22,31</sup>.

- **Helping students to find motivation and meaning**

To acquire students' engagement, teachers may help students to find the motivation to learn. They can do so by helping them to understand the importance of the taught content. This invites teachers to present the learned information in a way that it becomes meaningful and useful for the students and to select topics that interest them. Using authentic material helps to make the learning more significant. Having clear objectives outlined to the students may also help them attach meaning to the content. Using games, stories, as well as the strategies and frameworks presented below, also influence motivation<sup>17,22,26,27,29,31</sup>.

- **Enhancing memory**

Teachers can help students learn English by deliberately stimulating and strengthening their memo-

ry. They can strengthen their long-term memory by relating new information with previous knowledge. Besides, adolescents' brain relies more on declarative memory than procedural memory. It entails that they will benefit from engaging in explicit learning of vocabulary and grammar. Though, bringing it to life through a direct application is essential. In addition, enabling students to relate to the learned information and teaching within a context allows the further activation of the episodic and semantic memory. Implicit memory (procedural memory) also needs to be stimulated to achieve language proficiency and automatic use of the language. To do so, teachers may provide opportunities to practice the language without paying specific attention to the form but more to the meaning. Students need to be exposed to the language through listening activities, role plays, simulations, and dialogues for instance. Multimedia can also strengthen procedural memory.

Declarative memory and procedural memory can be strengthened through spaced repetition and retrieval practice. This implies spacing topics throughout the academic year and guiding the learners to space their study time. Teachers can make quizzes as an informative assessment. Spaced retrieval practice is also beneficial. That means assessing twice the same content. The working memory can also be stimulated by leading the students to concentrate on few things at a time. Ensuring that students process and understand the learning content<sup>21,22,24-29,31,32</sup>.

- **Regarding error as a learning tool**

Making mistakes forms part of the language learning process. Teachers must ensure that their students regard error as a learning opportunity. It also entails the need to create a space for constructive feedback. Teachers can make informative assessments. Consequently, students can be aware of their mistakes and improve. Such feedback also enhances memory<sup>22,26,29,31</sup>.

- **Using the power of association**

Teachers may assist students to make associations. They can connect concepts and content, groups of words, and visuals, and link their native language to the target language when relevant. In this way, students can make their own rules, find meaning, take ownership of their learning, and enhance their memory<sup>26,27</sup>.

- **Multi sensorial activities**

To ensure understanding and enhance retention,

teachers may make use of diverse ways to explain the learning content including grammar, syntax, and vocabulary. A multi-sensorial approach activates different parts of the brain and enhances language processing. It implies exposing students to a variety of stimuli and activities including reading, speaking, listening, movement, and the use of visual materials. The use of multimedia and technology can help to achieve this goal<sup>17,18,22,24,26-30</sup>.

- **Fostering social interaction**

Knowing that the brain is social, teachers should foster social activities. Besides, it enhances students' participation and engagement. Likewise, it strengthens students' memory as the brain will regard the information as relevant, meaningful, and worth remembering. It can be achieved through role-plays, games, small group activities, group debates and discussion<sup>26-29,31</sup>.

- **Bringing health into the language classroom**

Oxygen intakes and water are necessary to enhance concentration and learning. Exercising increases blood flow which clears out toxins that can deteriorate cognitive functions. Consequently, it raises concentration, motivation, and confidence, and reduces impulsiveness. Therefore, language teachers can make learning healthy by giving learners the opportunity to move. They can get students out of their seats by allowing them to stand up to get handouts or to handle papers. They can stand up to answer questions. They can play games and do group activities (partially) standing up. Students and teachers should be allowed to drink water<sup>18,30</sup>.

- **Self-evaluation**

Since there is always room for improvement, teachers need to evaluate their work and see if the applied strategies achieved the desired results. In fact, their efficiency may depend on many circumstances<sup>26</sup>.

### Frameworks

This paragraph presents frameworks within which the above findings can be applied. Teachers can use different approaches to foster students' engagement and learning. They can promote diversity of thoughts. They may give students opportunities to develop their ideas and display their skills. Allowing them to make decisions and express themselves in different ways.

**Exploratory learning** can be a means to that end. Students can be led to research a question, a topic, or

a debate<sup>27</sup>. **Content-based learning** also grants flexibility to teach in a brain-friendly manner. **Task-based learning** allows to progressively increase the level of difficulty. It can trigger the reward system in the brain and foster motivation<sup>26,29</sup>. Likewise, **project-based learning** allows to foster motivation, and exploration and gives room for creativity for both the teachers and the learners<sup>29</sup>.

The following highlights more specific strategies to improve the language per se.

- **Speaking**

Older children tend to struggle with pronunciation. This may be due to their native language and second language separation in Broca's area. Therefore, emphasis should be put on speaking activities such as skits and conversations<sup>17,26</sup>.

- **Pronunciation and grammar**

By virtue of the brain's plasticity, productive skills are connected to perceptive skills. This entails that pronunciation is linked to grammar. When improving pronunciation, grammar will likewise progress. This means that when studying grammar, stress must also be put on pronunciation<sup>18</sup>.

- **Listening**

Using technology can help improve students' listening skills. Moreover, it helps to bring motivation and engagement. Students often appreciate having feedback from a computer rather than from the teacher. Listening skills can be strengthened by mixing listening and vocalisation<sup>17,33</sup>.

- **Vocabulary**

Vocabulary is important to develop any aspects of the language (reading, writing, listening, and speaking). The brain forms networks containing a group of associated words. In a way that the activation of words from a same network is rapid while the activation of words from different networks takes a longer time. Teaching and learning vocabulary by connecting words through categories with mind maps, webs and clusters can help the brain expand its lexicon<sup>33</sup>. Students may also make associate words together with images or mental visualisation. By the same token, teaching idioms and lexical phrases, meaning larger chunks of words, is important. They are also stored in a network. Besides, the use of expressions activates the basal ganglia implicated in learning<sup>20</sup>. Such groups of words are often not meaningful by themselves. It is important to help students under-

stand them through discussion. The use of a journal to keep idioms and larger chunks of words is recommended<sup>20,33</sup>. Examples of larger chunks of words are from groups such as “by the way”, and “happy new year” to expressions like hearing “from the horse mouth”.

#### • Reading

To read, the brain needs to attach a sound to a letter. This is not a natural process. The brain needs to be taught how to do it. Second language learners often face the issue of not being able to recognise a word. This may be a phonological difficulty. Teachers may help their students by teaching phonological aspects and word recognition. To practice reading and pronunciation, students may learn phonemes and words by recording themselves and receiving feedback. Teachers, as well as computer applications, can provide feedback<sup>18,26,27,33</sup>.

#### • Syntax & Writing

Language learners also need to know how the syntax differs from their native language. They need to understand how a sentence is built in English. For instance, in Spanish descriptive adjectives are often placed after the noun they describe, while in English it is normally placed before. For example, the “talented singer” and “el cantante talentoso”. Sometimes transfer may occur, that is when an individual relies on their native language to understand the syntax of the target language. Pointing out both similitudes and differences contribute to the learning of syntax. Teachers may lead students to practice sentence formulation through mapping, graphs, and chart<sup>33</sup>.

### Extract Didactic Guide exemplifying how to incorporate these strategies within a teaching-learning plan

#### 1. Objective of the learning resource

Using a neuroscience-based approach to:

1. Acquire vocabulary related to social media.
2. Improve listening skills in the context of social media.
3. Improve speaking skills in the context of social media.
4. Improve writing and grammar skills in the context of social media.

#### 2. Target group

The didactic guide is designed for teachers working with high school students from the Spanish “bachillerato” level. They are normally between 16 and 18 years old. However, it can also serve teachers working with adolescents and adults.

#### 3. Introduction to the didactic guide

Name of Didactic guide: A neuroscience approach to teaching English to adolescents.

Function: Guiding teachers on how to teach English and put into place a learning environment respecting how the brain learns

### Part I. Neuroscience-based principles affecting [language] education

To achieve a brain-friendly learning environment, teachers should stimulate certain elements. Throughout all the sessions, teachers need to foster the following characteristics to facilitate and optimise the learning of students. (Figure 5).

#### Approaches to adapt to adolescents

- Avoiding cognitive overload (reducing the items).
- Reducing stress.
- Fostering social interactions.
- Promoting a growth mindset; praising process rather than performance, believing in students' capacity to learn.
- Providing positive and constructive feedback.
- Playing games.



**Figure 5.** Learning in the brain. Emotion, motivation, and attention highly contribute to the process of information. Designed by the author.

- Using exploratory learning.
- Allowing students to choose meaningful tasks.
- Setting achievable and exciting learning goals.

**Table 3.** Neuroscience principles to consider in the teaching-learning process

Emotions	Involving emotions in education Building a non-threatening environment Avoiding undue stress
Motivation	Giving constructive feedback Indicating the relevancy of the content Providing clear learning goals
Attention	Presenting new and relevant stimuli Using multisensory stimuli Presenting the information in a brief, precise and clear manner Taking breaks
Memory	Giving feedback Spacing the learning Using a variety of methods Practicing and rehearsing the content

Note. Created by the author

## Part. II. Developing language skills through the insertion of neuroeducation principles

Part I of the guide provides the importance to trigger attention, motivation, memory (implicit and explicit), positive emotional response, and social interaction that should be stimulated in each session.

The following is a guidance on how to apply neuroscience principles within the teaching of core language skills. It has selected themes and objectives that can be encountered in English curricula. It aims to provide practical tools that teachers can apply in their classrooms.

Social media has been chosen as a thematic since it can be a subject of interest to teenagers. In this way, the teaching-learning process would spark curiosity and interest. They will be able to rely on previous knowledge since they know a lot about it. And it will be significant and meaningful to them and more likely to improve learning outcomes.

At the end of each session, students are invited to reflect on what has been learned throughout the class. They can write down in a notebook what they

have learned and how it relates to previous knowledge, so they can strengthen their memory.

### Objective 1: Acquiring vocabulary taking into account neuroscience principles

#### Objectives

- Introducing the topic of social media
- Learning vocabulary

#### Content:

- Social media and vocabulary

#### Resources:

- White paper for mind map
- Quiz
- Computers & Internet
- Projector

#### Activities and instructions:

(1) The teacher clearly presents the learning goals to motivate students, catch their attention, and generate emotions. (5 minutes)

(2) Social Media Logo's quiz with Kahoot to foster participation, engagement, positive emotion, and attention. (15 minutes)

(2) The students make a mind map in pairs on social media vocabulary found on the dictionary and the internet, sharing with the class, and completing with the response of peers and teachers. The teacher gives feedback and praises effort. To strengthen memory as the brain codifies vocabulary in a network. (30 minutes)

(3) The teachers and the students reflect on the session. (5 minutes)

### Objective 2: Improving listening skills in the context of social media taking into account neuroscience principles

#### Objectives:

- Identifying phoneme, grapheme, and words

#### Content:

- Audio and videos related to social media

#### Resources:

- Computer /projector
- Pen drive with videos and audio
- Speakers
- White paper

#### Activities and instructions:

(1) The teacher explains the learning goals. (5 minutes)

(2) Listening game. The students play in pairs. The

teacher asks the students to listen to audio, or a video related to social media and the teacher asks how many times they can hear a phoneme, a grapheme, or a word. For instance, the teacher asks how many times you can hear the phoneme /k/ in the following audio. The extract should not be longer than 3 minutes. The students write down the answer in pairs. The same principles apply to graphemes and words. After each question, the students share their answers with the teacher. The latter indicates who is correct. *To foster motivation, participation, social interaction, attention, relevant emotions, and a playful activity.* (40 minutes)

(4) The teachers and students reflect on the session. (5 minutes)

### Objective 3: Improving speaking skills taking into account neuroscience principles

#### Objectives:

- Presenting yourself as an influencer

#### Content:

- Speaking and acting as an influencer on social media

#### Resources:

- Video
- Computer/projector
- internet

#### Activities and instructions:

(1) The teacher explains the learning goals. (5 minutes)

(2) The students watch the presentation video of a famous content creator on Instagram (5 minutes) To generate attention, motivation, and emotion.

(3) Inspired by the video, students create a similar presentation. They can invent the character, the platform he uses, the content he creates and so on. And, then they present it to the class. *To foster exploratory learning, creativity, motivation, and implicit memory.* (40 minutes)

(4) The teachers and students reflect on the session. (5 minutes)

### Objective 4: Improving writing and grammar skills taking into account neuroscience principles

#### Objectives:

- Improving writing skills and syntax
- Writing and using the conditionals

#### Content:

- First conditional
- Syntax
- Social media

#### Resources:

- Notebook to write sentences

#### Activities and instructions:

(1) The teacher explains the learning goals and the context in which they apply. (5 minutes)

(2) The teacher asks questions with conditionals to discuss with the whole group. Calling on volunteers. For example, what will you do if you become famous on social media? *To foster interest, attention, participation, emotions, and meaningful learning.* (5 minutes)

(3) The teacher explicitly introduces the first conditional. The teacher explains the uses of conditionals and the formation with relevant examples. *To stimulate explicit memory.* (15 minutes)

(4) Sentence diagram

The teacher shows an example of a sentence diagram with the first conditional. A sentence diagram is a picture of a sentence, it allows one to visualise how the words relate to each other and what is their function. In pairs, the students create a sentence diagram with a sentence answering the questions asked at the beginning of the session. The teacher goes to the pairs to provide positive and constructive feedback. *Multisensory stimuli, explicit memory, social interaction.* (25 minutes)

(5) The teachers and students reflect on the session. (5 minutes)

### Discussion

Up to this day, many scientists, educators, and linguists around the world have researched the contribution of neuroscience to education, including the teaching of a second language. Especially in the last decade, there has been a neuroscience boom. Researchers have sought to translate neuroscience findings into education as well as foreign language teaching. For instance, Kwedju published an article where she investigated the application of educational neuroscience to the teaching of foreign languages<sup>25</sup>. She did not specify English as a second language, but her research remains relevant as it serves a similar purpose to this article. She highlighted the importance of having efficient lessons where students

can upgrade their skills and cultivate their interests in learning the language. In the same way, this research observed a shortcoming in the language education system. In addition to improving the efficacy of language teaching, it seeks to help teachers to create a positive learning environment. Allowing students to relish language learning and paving the way for future successful learning experiences.

Besides, this article puts emphasis on the brain's ability to learn at any age along with teachers' ability to trigger its potential. This article draws attention to the importance of focusing on creating an efficient learning environment for students. Therefore, it invites both teachers and learners to believe in older children and adults' capacity to learn another language. In a similar vein, Kweldju as well as Thadphoothon, who did a bibliographic on brain research and language instructions, also mentioned as a principle that people can learn languages at any age<sup>18,25</sup>.

The brain still has lots of mysteries to unfold. Further neuroscientific investigations on how the brain learns a second language are necessary. Most of the sources concerned how the brain learns in general and the application of these principles within the teaching-learning of a second language. Bearing in mind that this research was written in 2021 and was limited to sources published within the last 5 years, few recent theories were found. This calls for further neuroscientific research specifically studying and observing how the brain learns languages. By the same token, researchers need to ensure that their findings can be translated and understood by the concerned actors. Some sources were analysed and seemed pertinent but were challenging to comprehend and retrieve results that language teachers can apply in their occupation. As pointed out in previous studies, there remains a gap between the neuroscience theory and the realities and complexities of classrooms<sup>26,27,29</sup>. Hence, this research sought to provide practical tools and strategies derived from neuroscience insight.

More studies applying the findings and providing feedback from teachers and learners are also desirable as done in the research of Po Lan Sham. The latter sought the "Significance of Neuroscience for Teaching English as Second Language (TESL)"<sup>28</sup>. She did a questionnaire to obtain adult learners' feedback on the efficiency of a course based on neuroeducation principles. Applying neuroscience to education

leads to focus more on the students. It seems relevant to receive regular feedback from students not only for the purpose of research but also as a pedagogical practice.

Though, it is necessary to stress that there isn't one perfect method to teach languages. As emphasised throughout this research, the use of a variety of methods is welcome. Teachers are invited to try different approaches and adapt them to their context. Likewise, Filipini Cearon I and Pedoroso de Moraes Feltes H call teachers to experiment neuroscience findings in the classroom<sup>26</sup>. A question arises as to whether neuroscience should be inserted into the training of language teachers. The latter uphold that it would be relevant. In agreement with these authors, it seems beneficial for teachers to acquire some basic knowledge through their curriculum or as continuous training. Being at the forefront of education, they need to be aware of brain function and how to stimulate it. Recent research also mentioned that both the initial training and continuing professional development of teachers play a crucial role in the quality of education<sup>27</sup>. Thadphoothon determined that brain research is not enough, and traditional teaching should not be abandoned<sup>18</sup>. As mentioned in Borrueco Rosa and in line with her approach, neuroscience is put at the service of teachers and the educational system<sup>22</sup>. It comes to enrich current practice.

Based on cognitive neuroscience, Borrueco Rosa created a didactic proposal to teach German to young children. To this end, she did a bibliographic review of research studying the learning process from a neurocognitive perspective. Based on that research Borrueco Rosa put into place a teaching-learning model optimising the traditional model by inserting pertinent neuroscience findings within her didactic proposal<sup>22</sup>. She found that language objectives need to be framed not only in terms of conceptual criteria but also in considering the child's neurocognitive process. She, therefore, favoured an interdisciplinary method to the teaching of language where education and neuroscience interact. She identified key aspects to stimulate the learning process namely attention, emotion, and memory. She focused on boosting a positive emotional response. As a result, she produced a didactic resource containing activities stimulating these factors. Likewise, Filipini Cearon I & Poderoso de Moraes Feltes argued in their bibliographic review that neuroscience has a

role in the teaching and learning of language. They stipulated that it helps to understand how the brain functions and which areas of the brain need to be stimulated. It confirmed the importance to consider the enhancement of attention, emotions as well as memory within the teaching of a second language. In accordance with these recent studies, this article underlines the importance of these elements and seeks to illustrate how to take them into account within the teaching of English as a foreign language.

## Conclusions

This research sought to learn from the broad field of neuroscience how to improve the teaching-learning process of English as a second language. Why neuroscience? Because it is the field expert in the functioning of the brain, which is a complex and marvellous organ responsible for the performance of cognitive functions such as learning and language. The question arose as to how this discipline can actually help teachers foster the learning of English in high school students. Simply answered, by showing which elements need to be stimulated to achieve learning. It entails building the teaching process based on what neuroscience informs. As a result, teachers can teach to the rhythm of their students' brains. In this context, neuroeducation studies neurocognitive aspects which can enhance the learning-teaching process and outcome. But what are such elements that teachers can stimulate to facilitate the learning of English?

To answer this question, how the brain learns was a main point of investigation. Learning in the brain is a highly elaborate system. This article strived to identify key elements and concepts relevant to the purpose of teaching. Teachers can positively trigger the motivation system in the brain to help students engage in learning by creating an interesting and rewarding learning experience and by giving constructive feedback. Attention is also an important factor that teachers can cultivate through positive emotions, new and relevant information, diversity in the presentation of content, the presentation of brief, precise and clear information as well as leaving room for breaks. Teachers can also intentionally enhance their student's memory through rehearsal, variety in teaching methods, feedback, spacing and involvement of relevant emotions. This article con-

cerns the teaching of high school students, that is to say, adolescents. In this regard, it further specified the importance of adapting to the neurobiological development of the target students. Educators teaching English to adolescents should particularly focus on reducing stress, promoting the reward system through feedback, diversifying the way of teaching, strengthening working memory, fostering social interaction, and promoting a growth mindset.

Additionally, this research looked specifically at what neuroscience can inform teachers about language acquisition in the brain. First, it emphasised the importance of the concept of neuroplasticity, pointing out that older learners can as well successfully learn a language despite the Critical Period Hypothesis. It drew attention to focus on exposing learners to a suitable learning environment likely to generate results. Besides, the research observed brain areas involved in language. Despite, the dominant involvement of the left hemisphere in language, both sides of the brain play a role in language learning. This confirms the importance of an integral and multimodal approach to teaching. Furthermore, acquiring a second language implies the involvement of memory systems. This thesis found that for older children, adolescents, and young adults both declarative and procedural memory come into play, but they have a more enhanced declarative memory. Meaning that language teachers should appeal to their student's declarative memory while giving room for their implicit memory to develop. Concrete strategies to apply neuroscience findings include the use of stories, games, multisensory activities, social activities, movement during the lesson, mind-maps, graphs, and technology. Content-based learning, exploratory learning, task-based learning, and project-based learning are possible frameworks to apply such strategies. Techniques and principles derived from neuroscience complement each other and often work together hence the repetition. As often read in the literature, emotion drives attention, which leads to learning.

When discovering the results of this research, some teachers may recognise some of their practice and approach to education. Neuroscience may not necessarily bring radical and ground-breaking changes. This thesis does not claim to do so. The matter is not really about it being innovative or not. But it is about being intentional and acting in an informed

manner. It is a question of focusing on seeking to adapt to the learner's brain and creating a positive learning experience. Consequently, the way to their present and future participation in learning endeavours is paved. Students are free from mental blocks and frustrations and prepared to step into the adult world with a growth mindset.

The guide which was produced within the results of this research is a practical illustration of what a neuroscience-based language session may look like. It includes key principles and strategies aforementioned. It does not pretend to be the model par excellence. In sum, it invites teachers to tailor the lesson to the way their particular students learn the best.

To progress at the rhythm of their brain. Knowing that sometimes the beat may change. Being flexible enough to follow the tempo and restore harmony in the teaching-learning process when necessary.

### Limitations

It would have been desirable to apply the findings of this research, but it was not possible to do it within the scope and time available for this research. Therefore, it is presented as a guideline and invitation to experiment.

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