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NEUROSCIENCE FOR BEGINNERS: THE HIPPOCAMPUS AND ITS ROLE IN LEARNING, REMEMBRANCES AND MEMORIZATION

NEUROCIENCIA PARA PRINCIPIANTES: EL HIPOCAMPO Y SU PAPEL EN EL APRENDIZAJE, LOS RECUERDOS Y LA MEMORIZACIÓN

ROQUE ANTÔNIO MOURA | roque.moura@unesp.br | UNESP / FATEC SJC
CARLA REGINA MOURA ANDRADE | mouraandrade@prof.educacao.sp.gov.br | UNITAU
MÁRCIA REGINA DE OLIVEIRA | oliveira.marcia@unitau.br | UNITAU
ARCIONE FERREIRA VIAGI | arcione.fviagi@unitau.br | UNITAU
MESSIAS BORGES SILVA | messias.silva@unesp.br | FEG / UNESP

ABSTRACT

A análise de custos de produção é essencial para assegurar a competitividade, lucratividade e sustentabilidade empresarial. Neuroscience applied to education offers fundamental support for understanding how the brain processes and stores information. The present study aimed to disseminate the crucial role of the hippocampus in the organization of learning and the memory consolidation process. The methodology consisted of an extensive bibliographic review, correlating neuroscience concepts with the CDIO educational initiative (Conceive, Design, Implement, and Operate), using keywords such as hippocampus, learning, cognition and memorization. The results and discussions evidence that the hippocampus, located in the medial temporal lobe, acts in conjunction with neurotransmitters to transform short-term memories (working memories) into consolidated memories (long-term). The analysis of the case of Patient H.M. reinforces that the integrity of this structure is vital for the formation of new explicit recollections and for spatial navigation, although implicit memories, such as priming, may occur without conscious intention. It is concluded that the adoption of active and practical methodologies (learning by doing), the student acts as the protagonist in team-based problem solving, favors neuroplasticity and the fixation of learning, simultaneously developing technical competencies and socio-emotional skills.

Keywords: Learning. CDIO. Hippocampus. Consolidated memory. Neuroscience. Memorization.

RESUMEN

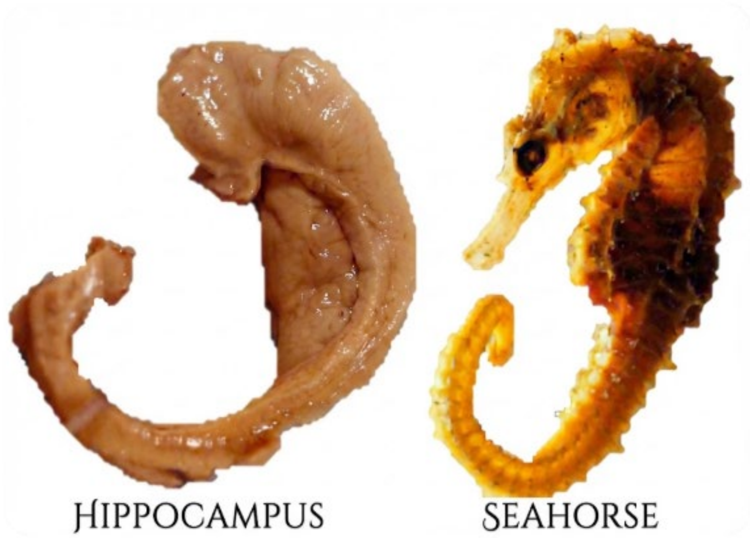
La neurociencia aplicada a la educación ofrece un apoyo fundamental para comprender cómo el cerebro procesa y almacena la información. El presente estudio tuvo como objetivo difundir el papel crucial del hipocampo en la organización del aprendizaje y el proceso de consolidación de la memoria. La metodología consistió en una extensa revisión bibliográfica, correlacionando los conceptos de neurociencia con la iniciativa educativa CDIO (Concebir, Diseñar, Implementar y Operar), utilizando palabras clave como hipocampo, aprendizaje, cognición y memorización. Los resultados y las discusiones evidencian que el hipocampo, ubicado en el lóbulo temporal medial, actúa en conjunto con neurotransmisores para transformar la memoria a corto plazo (memoria de trabajo) en memoria consolidada (a largo plazo). El análisis del caso del paciente H.M. refuerza que la integridad de esta estructura es vital para la formación de nuevos recuerdos explícitos y la navegación espacial, aunque los recuerdos implícitos, como el priming, pueden ocurrir sin intención consciente. Se concluye que la adopción de metodologías activas y prácticas (aprender haciendo), permite que el estudiante protagonice la resolución de problemas en equipo, favorece la neuroplasticidad y la fijación del aprendizaje, desarrollando simultáneamente competencias técnicas y habilidades socioemocionales.

Palabras clave: Aprendizaje. CDIO. Hipocampo. Memoria consolidada. Neurociencia. Memorización.

1. INTRODUCTION

The hippocampus is a small structure located within the brain, specifically in the medial temporal lobe region, forming part of the limbic system. It possesses the curious appearance of a seahorse, which is, in fact, the origin of its name: in Greek, *hippos* stands for horse and *kampos* for sea, combining to form *hippokampos*, meaning seahorse, due to its characteristic shape, as illustrated in Figure 1 (Amthor, 2017; Nicolelis, 2020; Tieppo, 2019; Moura²; Oliveira, Silva, 2023).

Figure 1 | Resemblance of the hippocampus to a seahorse



Source: Adapted from Facebook (2015).

Ensuring inclusive, equitable, and quality education, promoting lifelong learning opportunities for all, is a universal call by the United Nations (UN, 2023).

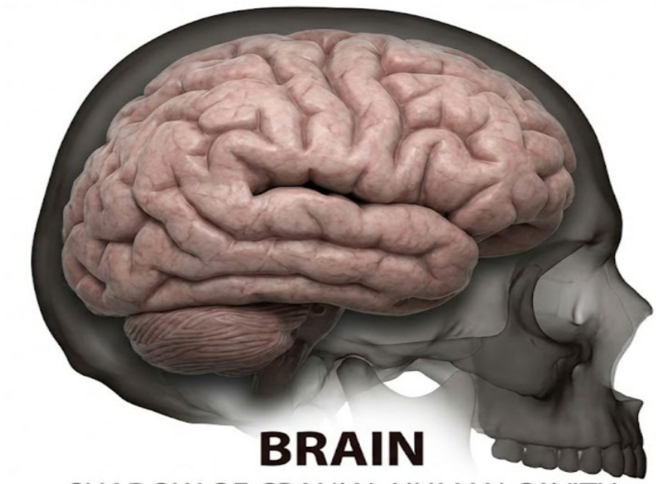
In this regard, neuroscience and technology, when combined in the teaching-learning process, have brought significant contributions to education. They allow for the development of new evidence-based teaching and learning methodologies, based on the principle that skills can be trained and improved through repetition (Amthor, 2017; Goulart et al., 2024).

However, it is important to remember that technology is a tool and cannot completely replace the human role in the transmission of knowledge within an educational environment. For it is educational technology, facilitated by dialogue (Benevides et al., 2025), that makes it possible to teach how to think rather than simply repeating crumbs of information; indeed, this is what humanizes education (Repef, 2022).

2. LITERATURE REVIEW

The brain is associated with functions such as memory, intelligence, reasoning, language, behavior and reason. It is located within the cranial cavity. The brain, the largest part of the encephalon, is responsible for the core of intelligence and learning in our body and is also the most complex organ (Figure 2) in the human organism (Nicolelis, 2020; Tieppo, 2019; Kocak et al., 2019).

Figure 2 | Brain: core of intelligence and learning



Source: Adapted from Ach (2023).

According to Amthor (2017), the human brain weighs, on average, 1,380 grams and contains about 100 billion neurons which, during synapses, are responsible for information processing. The human brain is highly plastic, meaning that it can adapt and change throughout life, although it is divided into several parts, each with a function as shown in Chart 1.

Chart 1 | The main parts of the brain

Organ	Organic function of the main parts of the human brain
Cerebral cortex	Outer layer of the brain, responsible for thinking, reasoning, memory, and language.
Hippocampus	Involved in learning and memory, being essential for the memory consolidation process. Influences social behavior and spatial navigation sense.
Hypothalamus	Responsible for the control of vital functions: body temperature, thirst, hunger and emotions.
Thalamus	Responsible for receiving sensory information from the body and sending it to the cerebral cortex.
Cerebellum	Responsible for movement and motor coordination. Receives information from the body about position and movement and adjusts body movements precisely and smoothly.
Brainstem	Responsible for connecting the brain with the rest of the body. Injury causes respiratory problems, cardiac problems, movement problems, speech problems and cognition problems.

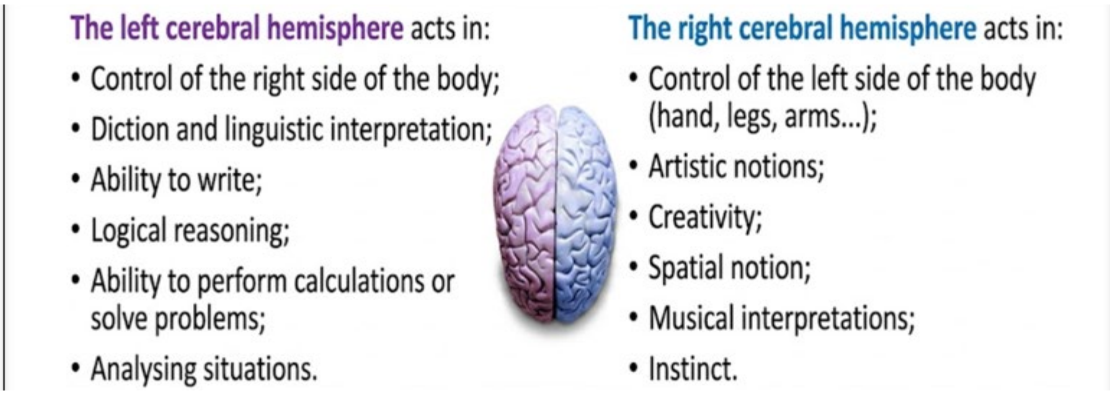
Source: Adapted from Amthor (2017).

Hemispheres of the human brain

The human brain possesses two cerebral hemispheres: one responsible for logic and the other for emotion. Each cerebral hemisphere controls the opposite side of the human body; that is, the left hemisphere controls the right side of the body, and conversely, the right hemisphere controls the left side of the human body (Nicolelis, 2020).

Statistically, the left hemisphere is dominant in about 97% of people worldwide, which explains the fact that most people have right-hand dominance, meaning they are right-handed. Figure 3 illustrates the functions performed by each hemisphere (Siegel, 2019).

Figure 3 | **Functions performed by each hemisphere of the human brain**



Source: Adapted from Siegel (2019).

The right and left sides of the brain complement each other, for example, in repetitive and standardized activities; although, Moura[3] et al. (2022) comment that one of the functions of collaborative intelligent machines is to free humans from repetitive, monotonous, and standardized tasks that are simple to execute.

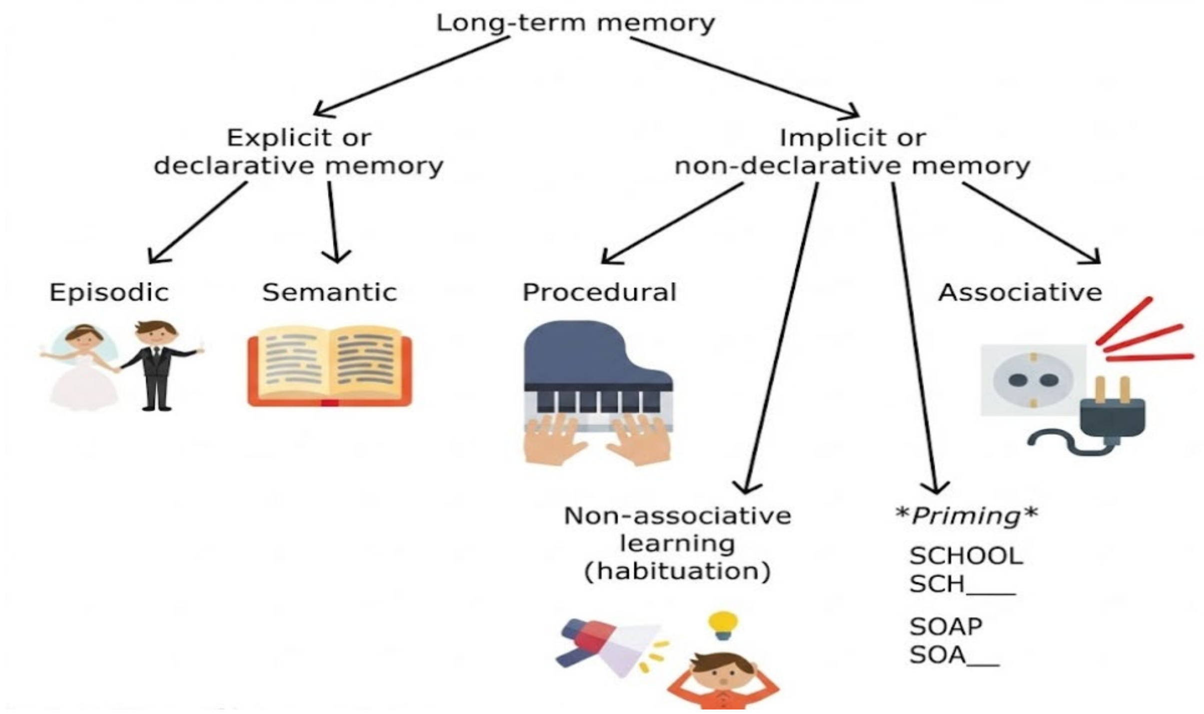
Types of Memory

According to Nunes, Costa and Souza (2021), memory is the brain's capacity to acquire, store, conserve, and retrieve information. Without memory, it is impossible to carry out daily activities, establish relationships, or learn and progress in our lives. The case of H. M. made it possible, for the first time, to highlight that non-declarative memories are based on neuronal circuits different from those of the medial temporal lobe and, above all, do not require conscious memory processes.

Human memory can be divided into:

- **<u>Short-term memory</u>:** is responsible for storing information for a short period of time (seconds to minutes) whilst we are performing a task or thinking about something. Information is quickly forgotten if it is not processed and transferred to long-term memory (Nunes; Costa; Souza, 2021; Kitamura et al., 2009; Moura[1] et al., 2024).
- **<u>Long-term memory</u>:** is responsible for storing information for a longer period, generally from hours to years. It is used to store knowledge, skills, and experiences. Long-term memory is divided into two types: declarative memory and non-declarative memory, as illustrated in Figure 4 (Cazzulino et al., 2016; Meira et al., 2018; Nunes; Costa; Souza, 2021).

Figure 4 | Types of human memory



Source: Nunes, Costa e Souza, (2021).

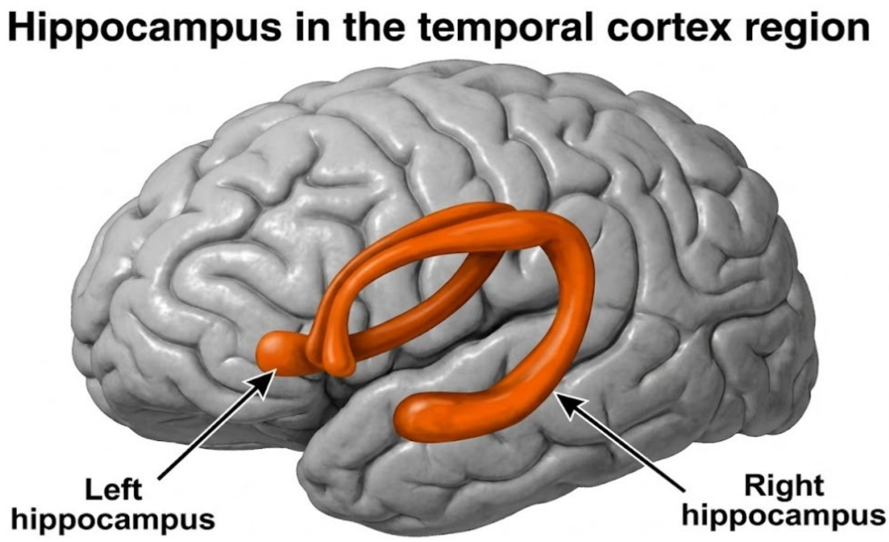
Emphasis is placed on priming memory (a type of implicit memory), where exposure to a stimulus influences a response to a subsequent stimulus, without guidance or conscious intention. This indicates that stimuli such as words, images, sounds, and smells, for example, the word ‘bicycle’, can act as a trigger to think of the word ‘ride’ or ‘fall’. This occurs because the word “bicycle” has primed one’s mind to think of other things related to the experience with a bicycle (Wyer et al., 2010; Marquis, 2015; Nunes; Costa; Souza, 2021).

Hippocampus

The hippocampus is responsible for ensuring that working or short-term memory is consolidated into declarative or explicit memory, which is stored voluntarily, and is, therefore, where facts and events that can be consciously recalled or 'declared' are stored. Damage, atrophy, or removal of the hippocampus can compromise the close relationship between teaching and memorization, as was the case with Patient HM. Due to a serious traffic accident, he required the removal of the hippocampus to be relieved (treated) of epileptic symptoms. He subsequently had his brain analyzed and monitored, and it was found that his pre-surgical memories remained intact, including childhood recollections; however, regarding post-surgical memory, he was no longer able to form new recollections. That is, Patient HM was left with only the memories and recollections from his pre-surgical life (Nicolelis, 2020; Tieppo, 2019; Uol, 2023).

The hippocampus possesses two structures, with one located on each side of the brain. Formerly known as the *Cornu Ammonis* (Ammon's horn), due to the fact that its shape resembles the horn of the Egyptian god Amun-Ra, and possessing a curved shape with coronal sections, it is located in the brain within the temporal cortex region (Figure 5), more specifically in the medial temporal lobe region, and plays a fundamental role in the formation and consolidation of memory (Amthor, 2017; Duvernoy, 2013; Nicolelis, 2020; Tieppo, 2019).

Figure 5 | Hippocampus in the temporal cortex region



Source: Authors (2026).

Within the brain structure, the hippocampus plays an important role in memory, learning, and navigation. In diseases such as Alzheimer's, the hippocampus is severely affected, and the capacity for spatial orientation, including moving from one room to another, is compromised. Furthermore, decreased dopaminergic and serotonergic activity in the hippocampus can lead to a loss of motivation and learning impairment (Boas et al., 2025), as well as mood and sleep disturbances (Macdonald et al., 2011; Gupta et al., 2010; Drieu; Zugaro, 2019).

The hippocampus, though a single functional system, is a paired structure, meaning you have one on the left side of your brain and one on the right. While they work together to help you learn and remember, research suggests they have slightly different "specialties," much like your left and right hands. Here is a simple breakdown of their functions:

The Left Hippocampus: The storyteller: Think of the left hippocampus as the librarian for words and facts. It is primarily involved in verbal memory. It helps remember things you hear, read, or say. Real-world examples: Recalling a conversation you had yesterday; Remembering a list of words or a phone number; Learning new vocabulary in a foreign language; If you hear a story, the left hippocampus helps you remember the plot and the names of the characters.

The Right Hippocampus: The navigator: Think of the right hippocampus as your internal GPS and camera. It is primarily involved in spatial and visual memory. It helps you remember locations, routes, and visual images. Real-world examples: Remember where you parked your car; Navigating your way through a new city without getting lost; Recognizing a face you have seen before; Mentally visualizing the layout of your childhood home.

In daily life, these two sides are almost always combined, they create a complete memory of the event. In this regard, there are studies on the role of neurotransmitters in the hippocampus aimed at developing new treatments for memory, learning, and navigation issues, as these neurotransmitters play interconnected and complex roles in hippocampal functioning. Alterations in the function of these neurotransmitters may be associated with memory disorders and neuropsychiatric conditions, such as Alzheimer's disease and depression (Squire, 2009).

Some hippocampal neurotransmitters are shown in Chart 2.

Chart 2 | **Neurotransmitters impacting hippocampal function**

Neurotransmitter	Transmitter Function
GABA (Gamma-Aminobutyric Acid)	Inhibitory neurotransmitter is essential for forming memories. In the hippocampus, it plays a role in regulating neuronal excitability and, when balanced with glutamate (excitatory), aids in proper cognitive function.
Glutamate	Excitatory neurotransmitter necessary for learning, playing a central role in hippocampal function. It acts on signal transmission between neurons and is essential in synaptic plasticity, allowing for memory of learning consolidation.
Acetylcholine	Excitatory neurotransmitter with a significant role in memory and learning. Its release is modulated by projections of nerve cells originating in the brainstem and extending to the hippocampus, favoring attention, short-term memory formation, and the learning process.
Dopamine	Excitatory neurotransmitter involved in motivation and learning.
Serotonin	Inhibitory neurotransmitter involved in mood and sleep with effects on the hippocampus by influencing synaptic plasticity and, therefore, affecting learning and memory.
Noradrenaline (Norepinephrine)	Neurotransmitter is influential in hippocampal function. Regulates alertness and attention. Affects memory formation. Released by the noradrenergic system of the brainstem, it acts on consolidated memory under strong emotional stress.

Source: Authors (2026).

Alzheimer’s and the hippocampus

Nearly thirty-six million individuals are affected by this degenerative disease, generally after sixty years of age, although it can also affect both young people and adults. The hippocampus, which facilitates behavior in social interactions, is affected by Alzheimer’s due to synaptic dysfunction and cognitive deterioration (Abreu, 2022; Milner, 2005).

Typical symptoms involve memory problems, as the patient tends to gradually lose working and short-term memory, forgetting appointments, places they have visited and, at more severe levels, their own family members, as well as experiencing disorientation in time and space. Some studies demonstrate that intellectually more active people, even with a predisposition for Alzheimer’s, may present a milder or later onset of the condition (Abreu, 2022; Squire; Wixted, 2011; Weible, 2013; Vikbladh et al., 2019).

Neurons and Synapses

The hippocampus is one of the few areas of the adult brain where neurogenesis, the emergence of new neurons occurs. Also called nerve cells because they are related to nerve impulse, these are excitable cells, capable of generating, conducting, and receiving stimuli as a functional and morphological nervous unit (Parasuraman, 2003). The synapse is the phenomenon by which short-term memories and even long-term memories establish new connections between neurons, transmitting information through the body in the same way that electricity propagates (Amthor, 2017; Pantano; Zorzi, 2009; Preilowski, 2009).

Learning and consolidated memory

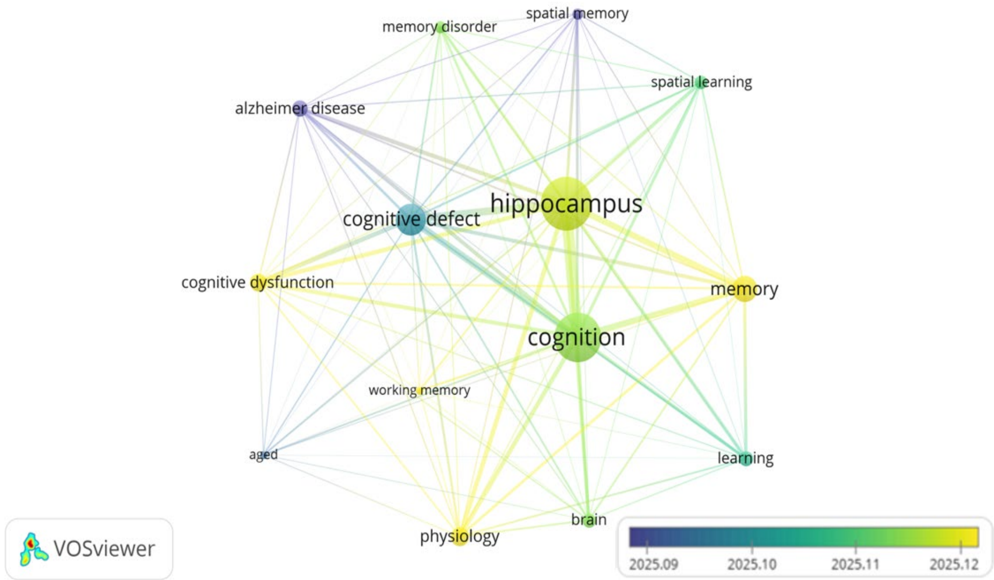
According to Pantano and Zorzi (2009), learning and memory are not processes that occur continuously. Declarative or explicit memory corresponds, effectively, to what everyone understands as memory, relating to facts and information acquired through learning. The transfer of learning and generated knowledge, and its storage as information by memory, are different stages. Mental or verbal repetition favors the transfer of learnt content to primary memory (working memory), and periodic reading allows new information related to the initial learning to be added to the system; this process is called memory consolidation (Costa, 2006; Kovãcs, 2020).

Procedural or implicit memory is slow, involves the association of sequential stimuli, and is stored after continuous training, not requiring conscious action but being inferred from the individual's skills or performance during task practice (Walker; Robertson, 2016).

3. METHODOLOGY

The methodology relied on extensive bibliographic research on the subject across available platforms, addressing the correlation between the keywords: "hippocampus", "learning", "memory", "cognition" and "spatial memory" as illustrated in Figure 6.

Figure 6 | Hippocampus and correlation between keywords published in recent decades



Source: Authors (2026).

The relationship between the keywords and respective publications demonstrated the importance of the hippocampus in memory formation, learning, cognition, and neurogenesis in preventing memory disruption, disease, and cognitive dysfunction (Eck; Waltman, 2025).

4. RESULTS AND DISCUSSIONS

4.1 Role of hippocampus

The hippocampus plays a significant role in the formation and consolidation of memory. Its main functions and activities are demonstrated in Chart 4.

Chart 3 | Activities of the hippocampus in learning consolidation

Regarding to ...	The hippocampus acts to ...
Memory	Create new memories, recall specific events, and transform short-term memories into long-term memories.
Consolidated memory	Store newly learnt information permanently and organize it so that it can be stored permanently in the cerebral cortex.
Spatial navigation	Provide spatial orientation, create cognitive maps of the environment, and allow individuals to locate themselves and move through space with ease.
Regulating emotions	Regulate emotions and process emotional information. As it is connected to other parts of the brain (amygdala), it is involved in emotional responses.
Neurogenesis	The process of forming new neurons. Essential for memory and learning.

Source: Authors (2026).

4.2 Discussions

Injuries or damage to the hippocampus can cause memory problems, such as anterograde amnesia or difficulty in forming new memories, and can also affect the capacity for spatial navigation and emotional stability (Amthor, 2017; De Moura et al., 2025; Cunha et al., 2021).

The functions of the hippocampus are relevant for the understanding of neurological conditions. When there is significant impairment of the hippocampus, the patient completely loses orientation and is unable to move from a chair to a bed in the final stage (Nicolelis, 2020).

Long-term memories are not stored in the hippocampus, only rapid memories. Furthermore, more effective memory consolidation is possible when the information is associated with an episode of great emotional impact (Amthor, 2017; Preilowski, 2009).

Learning and memorization do not occur simultaneously. In learning, the brain can acquire new information through the formation of new connections between neurons (Oliveira Junior et al., 2025); in turn, memory is the capacity to store brain information by altering the strength of the connections between neurons (Oliveira et al., 2025).

Learning is the process of acquiring new information or skills in an active manner, involving attention, comprehension, and the application of new information. Memorization, on the other hand, is the process of storing information in rapid memory and only later, through a passive process, involves the repetition and association of the absorbed information (Pantano; Zorzi, 2009; Kitamura et al., 2009).

However, memorization is an essential component of learning. One can quickly conclude that to learn something, one needs to memorize it first (Fernandes et al., 2025) nevertheless, memorization is not sufficient for learning, as it is necessary for the information to be understood and applied, for example, riding a bicycle. However, one only truly learns when one understands the interaction between moving the bicycle, balancing, having a sense of direction, and respecting others nearby (Costa, 2006; Kitamura et al., 2009; Repef, 2022).

To improve learning and memorization, the Project-Based Learning (PBL) methodology is one of the tools that aids in enhancing learning and memorization. A catalyst for learning within the concepts of active methodology can be technical and non-technical skills and competencies, capturing attention, verifying the extent of what is being taught, repeating information periodically, associating information with a peculiarity of the students' environment, and finally, practicing with the students what has been taught (Abreu, 2022; Squire; Wixted, 2011; Weible, 2013; Vikbladh et al., 2019).

4.3. Hands-on work as resources to facilitate learning

Broadly speaking, a hands-on work initiative promotes a more practical and applied approach to education, making students better prepared to face real-world problems through the development of transversal skills. Students, as the main protagonists, develop or enhance their technical and non-technical skills by working in teams involving creativity, communication, and problem-solving. Chart 4 demonstrates a more practical approach (CDIO, 2020).

Chart 4 | Activities of "Conceive, Design, Implement, and Operate".

Acronym - means	Developing a project and skills
C - Conceive	To conceptualize and create a project. It begins after understanding the problem and envisioning a viable solution. Requires technical skill.
D - Design	To form a multifunctional and interdisciplinary group. Everyone seeks the solution. Requires technical and behavioral skill.
I - Implement	After finding the viable solution, it must be validated. It is possible to iterate. Requires technical and emotional skill.
O - Operate	After testing the solution. It can be put into practice. Respect those involved. Requires behavioral skill.

Source: CDIO Initiative (2020).

CDIO initiative adopts principles and best practices serving as guidelines for the teaching-learning relationship, in addition to emphasizing technical and non-technical skills, preparing students for real-world challenges (CDIO, 2020; Da Silva Filho et al., 2025).

5. Final Considerations

This review research aimed to analyze the implementation of improvements in a learning process, highlighting the functions of the hippocampus as a crucial brain structure that plays a fundamental role in the formation and consolidation of memory and spatial navigation.

The skills supported by hippocampal activity are important for the development of social and emotional skills, such as empathy and cooperation. Teamwork is an important social skill that requires the development of aptitudes such as communication, collaboration, decision-making, and problem-solving, which can be easily achieved through the CDIO initiative.

This research adequately navigated through the types of memory up to their consolidation, covering scientific history and facts such as the CDIO initiative, which calls upon students to be the protagonists of their learning; conversely, teachers can only teach what they have already mastered.

In the assessment of competencies and skills, even if the student makes a mistake, they have learnt. The key lies in how they acted, decided, and interacted. Thus, even if assessments shift from being individual to involving students working in teams, they need to be both summative and formative. Finally, for neuroscience, learning and memorization go hand in hand but do not occur simultaneously. For example, priming memory, of the implicit type, is a phenomenon in which exposure to a stimulus influences a response without guidance or conscious intention.

As future work, introductory and review studies such as this one are suggested on other topics, such as learning during REM sleep.

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