Module 1 - Introduction

NEUROPEDAGOGY

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LEARNING OBJECTIVES

1. To explain what Neuropedagogy is and distinguish it from other Neurosciences, such as behavioural neuroscience, developmental neuroscience, cognitive neuroscience, developmental cognitive neuroscience
2. To explain how the brain works and learns, and understand and value the importance of this knowledge for the teaching practice.
3. To explain the guidelines for planning and adjusting teaching methods based on the factors that lead to better learning, as identified when learning about how the brain works and how it processes learning.

Expected learning outcomes:

Knowledge:

- Define neuropedagogy and associated concepts.
- Distinguish neuropedagogy from other neurosciences.
- List the parts of the brain and describe how they work.
- Describe how you learn through the functioning of the brain.
- Defend the usefulness of neuropedagogy in teaching performance.
- Outline the general principles of application of neuropedagogy in the classroom.

1. The definition of neuropedagogy and how was it born

1.1. Emergence of Neuroscience

The appearance of **neuropedagogy** is necessarily linked to the appearance of **neuroscience**, a term that brings together a compendium of scientific disciplines that are responsible for the study of the central and pathological nervous system (Anatomy, Embryology, Physiology, Biochemistry, Pharmacology, Psychology and Neurology) and in which, currently, other more modern scientific disciplines are joining, including Computer Science or Bioengineering.

This interdisciplinarity, which tried to combine the work of basic and clinical scientists, was especially evident in the decade of the sixties and early seventies with initiatives such as the foundation of the *International Brain Research Organization* (IBRO), the implementation of the teaching program of this discipline, *Neuroscience Research Program* , at the Massachusetts Institute of Technology in Cambridge (Massachusetts, United States) or the creation of the *Society for Neuroscience*, also in the United States (Paz et al. 2019, p. 209).

Although its origin has a significant biomedical meaning, marked by the study of the nervous system from different specialties, it is currently crucial for many other disciplines such as ethics, economics, politics or education (Farah, 2013).

The **nervous system** is made up of the brain, spinal cord, and neural networks. The goal of neuroscience is to understand how the nervous system works to produce and regulate emotions, thoughts, and behaviors, as well as basic bodily functions (Kandel et al. 2013). The nervous system is the network through which messages that arrive and leave the brain travel, which is responsible for making decisions.

During the twentieth century we witnessed the most revolutionary period in the growth and settlement of Neuroscience as a discipline, both in research and in the clinic. Such was the prominence of this science, that the last decade of the 90s was defined as "The decade of the brain". To emphasize this, Kolb makes a reflection that subscribes to this idea: "The twentieth century belongs to Neuroscience".

However, one of the main paradoxes that derive from this boom is the evidence that our knowledge, regarding brain functioning, is far from complete (Howard-Jones, 2014).

1.2. What is neuropedagogy?

Strictly speaking, the term neuroscience has always referred to the investigation of the structure and functioning of the nervous system from a physiological perspective and, therefore, would be equivalent to the branch of neurobiology. For this reason, in its beginnings, the concept of educational neuroscience only appealed to neurological studies on the functioning of the brain that were related to learning and memory. However, in recent years, we have found that the scientific evidence on how the brain learns that is most relevant to educational practice, comes especially from cognitive psychology and related disciplines. That is why the term educational neuroscience has been increasingly used in a broader sense than the original, grouping these disciplines under the same umbrella (Howard-Jones, 2010). In other words, the term has become synonymous with any discipline that uses the scientific method to analyze how we learn and specifically, in the field at hand, the sciences that study educational phenomena: pedagogy (neuropedagogy).

Neuropedagogy aims to build the educational process taking into account data on brain development, on effective methods of learning and teaching, on the organization of the brain from the peculiarities of brain development of students and educators. Thus, for its development, the contributions of pedagogy, psychology, physiology, and other cognitive sciences are taken into account.

For example, neurobiology investigates how learning occurs at the molecular, cellular, and organ and system levels, studying how the nervous subsystem acts as a physical support for learning-related phenomena. In recent decades, this discipline has benefited greatly from the possibility of "seeing" the brain of a healthy person in functioning while performing mental or motor actions, being able to appreciate which regions of the brain are activated above the usual.

Cognitive psychology is at a different level of study, which investigates how the brain obtains, manipulates, and stores information. This discipline does not study the physiology of the brain, but models its functioning from the evaluation of the changes that certain sensory or motor experiences cause in the behavior and skills of people, so it is much more capable of guiding us in educational practice than neurobiology. Cognitive psychology draws on advances in neurobiology to support its models and theories, acting as a bridge between scientific advances in how the brain works and education.

The main objective of neuropedagogy is, taking into account the individual characteristics of students and teachers, to analyze what are the optimal and most creative strategies for solving educational problems, using knowledge about the individual characteristics of brain organization and higher mental functions. For example, the different strategies between boys and girls, left-handed and right-handed and how these change in the various educational stages are analyzed.

In this way, neuropedagogy advances through some basic principles of the educational process such as:

- Offer ample opportunities for students to participate in a variety of content and forms of learning and cognitive activities, using different learning methods and techniques adapted to the age and characteristics of the students.
- Create an environment and circumstances suitable to satisfy the innate curiosity of the human being to learn (including eating and physical activity).
- Enhance the connections between what is already known and new learning. Understanding and learning occurs when the brain finds support in existing knowledge and perceptions.
- Organize the learning sequence logically so that the brain can create the connections properly. Chance and chaos complicate productive brain activity.
- Take into account emotions as a necessary element for productive brain activity. Learnings acquired in a favorable atmosphere are better remembered and establish more stable connections.
- Present the didactic material in a way that constantly interacts the general and the particular, induction and deduction. Analysis and synthesis are two thought processes in constant interaction in learning.
- Have internal factors (previous experience, emotional state, level of motivation, individual

characteristics of the student, etc.) and external or peripheral perception of the learning environment (general environment in the classroom, sound, light, etc.).

1.2.1. Different terms associated with neuropedagogy.

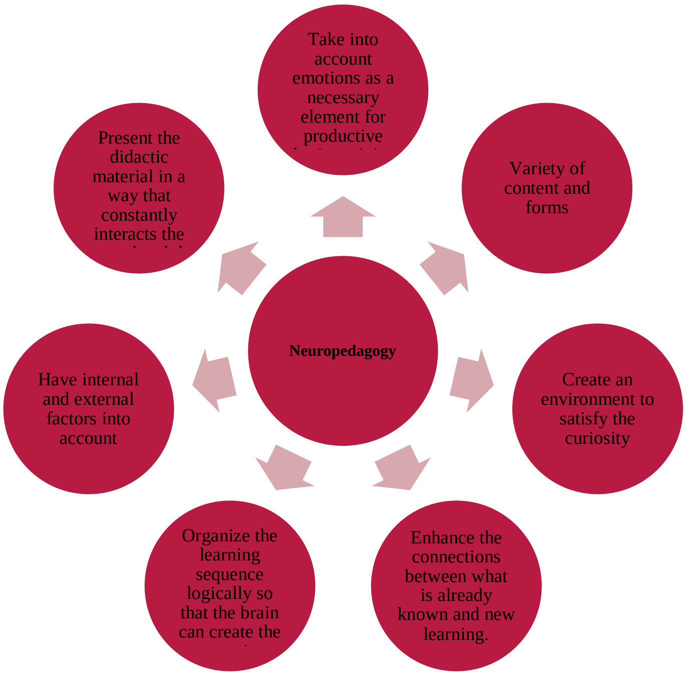
There are many terms associated with neuropedagogy, which, although they have slight differences, all could be used as synonyms at one time or another. The most common are **Neurolearning**, **Neurodidactics** and **Neuroeducation**.

- **Neurolearning**. Study the link between the brain and learning. For example, because there are certain moments in human development more sensitive than others for the development of certain learnings (Sousa, 2016).
- **Neurodidactics**. It is, without a doubt, the term closest to Neuropedagogy. It is the science that studies the adequacy of the didactic action to the brain functioning of each individual. That is, it studies the most appropriate way of teaching for each of the ways of learning (Tokuhama-Espinosa, 2010).
- **Neuroeducation**. It is the most general term and is defined as the science that establishes the links between neuroscience and its applications in education (Bruer, 2008).

In summary, we could say that Neuroeducation would be the most generic term that would encompass Neurolearning, closely linked to psychology (evolutionary and cognitive) and Neurodidactics or Neuropedagogy, which is the specific area that concerns us.

2. What does neuropedagogy bring to teachers?

Neuroscience cannot provide complete answers about what is best for learning, but instead explains how the brain works. Neuropedagogy tries to build bridges between neuroscience and learning.



In the scientific literature of the field in question, it is very common to find different results: studies that show the effectiveness of one method and others that reflect the opposite. Sometimes, it is unfruitful to compare educational methods because everything depends on the details, that is, on the multiple variables that come into play in each method. However, we usually classify didactic methods according to one of their variables, and it is usually not this variable that determines their effectiveness. Therefore, when we go to educational research, we must differentiate between studies that inform us about the presumed effectiveness of some methods with respect to others, and research that directly tries to find out which factors are those that share the methods that end up being effective. Many of these factors have to do with how the brain learns.

There is no infallible recipe for everything, it is the teacher who will have the last word when it comes to adjusting the methods to achieve the best results. And for this it is crucial that you know the principles of learning supported by scientific evidence. In this sense, rather than talking about evidence-based teaching, we should talk about evidence-informed teaching (Hattie, 2012). It is not a question of strictly applying specific methods that science has analyzed in specific situations, but of planning and adjusting the methods according to the particularities of the situation, with the help of what science can tell us about what factors lead to better learning from the knowledge that neuroscience gives us.

Since scientific advances in how the brain develops and learns have reached the general public, multiple pseudoscientific myths have crept into education, which have arisen from the misrepresentation or misinterpretation of scientific findings. These myths are a problem because they confuse us and lead us to make decisions and devote efforts in favor of practices that do not have any evidence. In general, they entail a waste of time that we could have dedicated to more effective activities, and, in the worst case, they can have a negative impact on learning. Some of these pseudoscientific myths about learning are (Sousa, 2011):

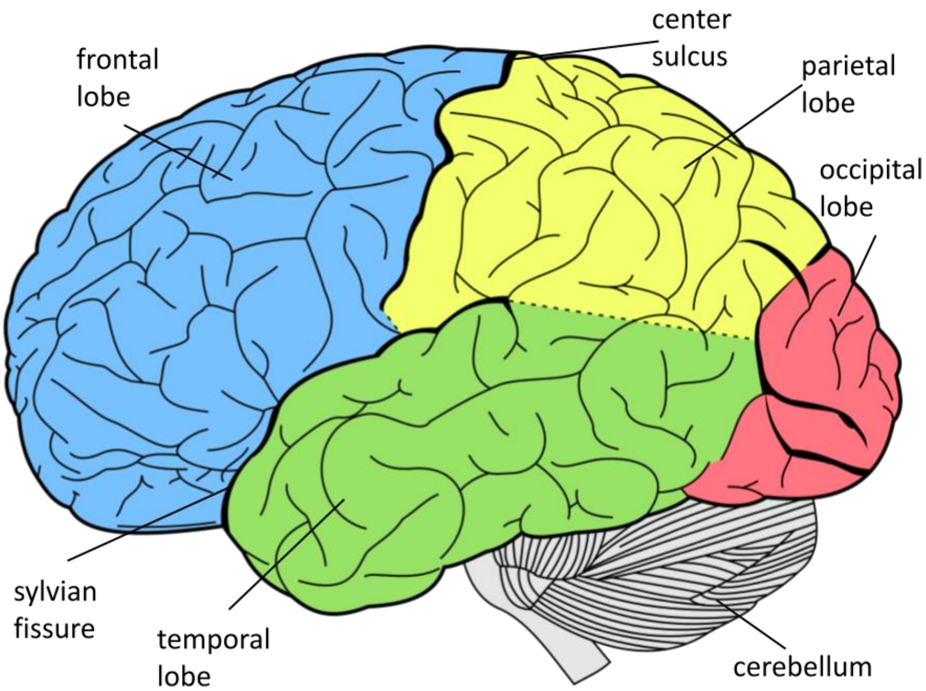
- People learn best when they receive information in their preferred learning style (auditory, visual, etc.).
- Environments that are rich in stimuli improve the brains of preschoolers.
- Certain differences in the dominance of one cerebral hemisphere over the other help explain some of the differences between students.
- We only use 10% of the brain.
- There are critical periods in childhood after which it is no longer possible to learn certain things.

There are eleven key aspects of the brain that allow us to deepen educational practice (Battro, Fischer & Léna, 2008):

1. Education alters the connections of the brain, so depending on how education is, it will generate more critical and reflective people, impulsive or submissive.
2. Positive reinforcement is key in learning.
3. Educational strategies that generate positive emotions should be used, so that learning is associated with pleasure.
4. A learner who is allowed to decide, evaluate, relate, etc., and who feels the motivating need to do so, will establish a better neural substrate, which will allow him to better assimilate new learning.
5. Collaborative and cooperative learning is more meaningful and involves the activation of many more neural networks.
6. The richer and more plural classes, which incorporate innovative and surprising elements, allow to improve the attention as it matures.

7. Stimulating the motivation of students and showing them models to learn to motivate themselves, is key to maintaining attention and the trigger of the competition of learning to learn.
8. The attitude of the teacher is key in the perception of the students about what they learn and the very fact of learning and must act as a model.
9. Transversal learning that includes intellectual, artistic, psychomotor, etc. activates wider areas of the brain, so there is a better fixation of learning and a greater ability to apply them.
10. It is essential to respect the maturing times of the brain and not to get ahead, as it can have counterproductive effects in the learning process.
11. Chronic stress is the worst enemy of learning since it contributes to forming impulsive people with a lower capacity to make decisions autonomously.

3. Anatomical organization of the brain



The **cerebrum** is the bulkiest part of the brain. It is described as the organ of thought and serves as the site of control of the nervous system; it allows the human being to possess the qualities associated with consciousness, such as perception, communication, understanding and memory (Kandel et al. 2013). The cerebral hemispheres consist of elevations (gyrus) and valleys (grooves); a longitudinal cerebral fissure separates the hemispheres that are kept connected through a set of fibers that constitute the corpus callosum. Each cerebral hemisphere is divided into lobes, which correspond, broadly speaking, to the overlying bones of the skull.

Frontal lobe. The frontal lobe is located in the anterior cranial fossa. The central sulcus divides the frontal lobe from the parietal lobe into a coronary plane. The gyrus anterior to the central sulcus is called the precentral sulcus and serves as the primary motor area of the brain. The rest of the frontal lobe is used in the modification of motor actions. It is in charge of deciding the appropriate motor behavior in each case. For example, when we place our hand differently to take a cup or a spoon, the way the hand acts is defined and decided in the frontal lobe. In the frontal lobe there is a band of tissue that acts as an anatomical map of our body, "the motor homunculus", where the size of each body segment is proportional to the complexity of the movement and action to be performed. Thus, the hand, fingers and face have, on this map, a greater extension than the shoulders or hips.

The frontal lobe is very developed in the human being hosting important non-motor tasks such as behavior planning, control of our emotions, reasoning, and judgment, which are complex functions not always easy to analyze if a patient has a stroke. The areas responsible for these skills are ahead of those devoted to motor function (premotor and prefrontal areas).

Parietal lobe. The parietal lobe interprets sensations coming from the body. The gyrus posterior to the central sulcus, the postcentral sulcus, is the primary area for the reception of these sensations. To act, we need information from our environment and our own body. Thus, continuing with the example of the cup of coffee, we could not perform such a simple task, if we did not detect through our senses the weight of the teaspoon we move, the size of it, the map of where our hand is and the route we must take. The parietal lobe is involved in the map of "where to act", integrating sensory information interoceptive (from our body: muscles, joints, tendons) and exteroceptive (from the outside). It is basically attributed sensory, associative functions, as well as recognition of space.

Occipital lobe. The occipital lobe is located above the tent of the cerebellum, in the posterior cranial fossa, and is mainly related to vision. It elaborates visual information, although it transcends the parietal and temporal lobes

Temporal lobe. The temporal lobe is located in the middle cranial fossa and is mainly related to hearing, as well as the place where, on its medial face, important structures of memory (hippocampus) and the unconscious emotional system (limbic system) sit.

In humans, a lateral shift of functions is recognized, so that the two cerebral hemispheres do not do the same. Evolution has been responsible for making the most of the brain through a division of labor between its two halves (the cerebral hemispheres). Thus, the right hemisphere focuses on nonverbal expression, perception and spatial orientation, and also on emotional behavior. Then, the right hemisphere thinks and remembers in images. Several studies have shown that people with a dominant right hemisphere study, think, remember and learn in images, as if it were a film without sound. These people are very creative and have very developed imaginations.

On the contrary, the left hemisphere (more developed in most human beings) is responsible for verbal development, which contributes to its production and understanding. In it there are two structures that are closely related to linguistic ability, the "Broca Area" and "Wernicke's Area" (areas specialized in language and exclusive to the human being). The specific function of the "Broca Area" is oral expression, it is the area that produces speech. The "Wernicke Area" has as its specific function the understanding of language since it is the receptive area of speech.

In addition to the verbal function, the left hemisphere has other functions, such as the ability to analyze, ability to make logical reasoning, abstractions, solve numerical problems, learn theoretical information, make deductions, etc.

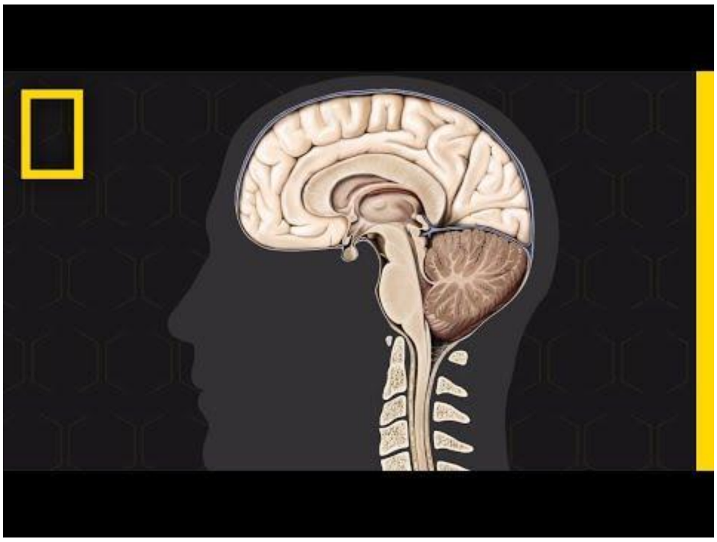
But the brain, despite dividing the work between different regions and hemispheres, functions as a unit, achieving in real time a coordinated and precise action. Below the cortical mantle (cerebral cortex) is the cerebral white matter through which bundles of nerve fibers cross, each with a different course and type of information. Below this white matter are located the deep gray nuclei (basal ganglia) that are involved in multiple functions, especially in motor behavior.

Brain development and cognitive maturation occur concurrently during childhood and adolescence (Casey et al. 2005). Brain regions associated with more basic functions such as motor and sensory processes mature first, followed by association areas involved in top-down control of thoughts and action. The total brain size is about 90% of adult size by age 6 years, the brain continues to undergo dynamic changes throughout adolescence and well into young adulthood.

At the fourth month of gestation, a differentiation of cells is observed in the fetus; similarly, neurons and glial cells are produced at an important rate. Through a migration process, these cells form the first brain regions that will ensure the most elementary functions, such as reflex movement, physical behaviors, and balance. The areas in charge of sensory stimuli, memory, and emotions are formed a little later: the cerebral cortex, which is the part of the brain that is associated with higher cognitive activities such as attention, synthesis, planning, reasoning, spatial imagination, and language.

While it is true that during childhood several important changes in mental abilities and brain maturation are noticed, the adolescent brain continues its development, even beyond adolescence and ends up reaching its maximum volume around the age of twenty-five. Even after reaching this peak the brain does not lose its plasticity. This plasticity is also manifested in the ability of certain cortical regions to assume functions that, in principle, would be carried out by regions that have lost their functionality, as a result of relatively minor damage.

If you want to know more about the parts of the human brain, as well as its unique defenses, like the blood-brain barrier, watch the next video:



Brain 101. National Geographic

For further information about the anatomical organization of the brain, check the additional resources:

- Kolb & Whishaw (2019). *Introduction to brain and behavior.*
- Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2019). *Cognitive neuroscience: The biology of the mind*.
- Ward (2020). *The Student's Guide to Cognitive Neuroscience.*

4. How does the brain learn?

Evidence allows us to believe that memory is organised in such a way that our memories and knowledge form networks where each element is connected to those with which it maintains a meaningful relationship (Sousa, 2010). In order to incorporate new knowledge, it must be connected to existing knowledge structures (prior knowledge) with which it has a semantic relationship. This is not a recent development; there are countless evidences from cognitive psychology and neurobiology that help to understand the phenomena related to learning (Vygotsky, Piaget, Barlett).

We learn when we connect relevant prior knowledge to the learning objective. The more connections we make, the stronger the learning will be and the easier it will be to retrieve it when needed because more different contexts will activate it.

The information processing that leads to better learning is observed using functional magnetic resonance imaging techniques, which show which parts of the brain are more highly activated than usual when we perform certain mental actions. It has even been possible to predict the likelihood of a stimulus being remembered according to the degree of activation of the frontal region of the brain.

If education affects the brain, and the brain is the organ that allows us to adapt to our environment and transform it, knowing how it is formed and how it works, how it learns, what motivates it, what it values most, how it retains the information it receives and how it uses it, will help us to fine-tune our educational strategies.

Memory is the faculty that enables us to learn, but we do not learn everything in the same way. There are different learning objects that involve different types of learning. For example, learning a skill is not the same as learning a concept. Research has shown that we have different types of memories that allow for different types of learning and different uses of information. That is, memory is not a single skill, but a set of skills that depend on different neural processes and structures. There is not one memory, but different memory systems that are the subject of study in educational research.

There is a lot of discussion about active learning, but it is sometimes confused with educational practices in which the learner does something ("**learning by doing**"). However, it is not about doing anything but about actively thinking about the object of learning, looking for meaning and contrasting it with their previous knowledge ("**learning by thinking**").

Any active learning experience must include activities that ensure that the learner is reflecting on what he or she is learning. There is an important difference here between teaching and helping to learn, and this is a well-researched topic: better results are obtained if learning is guided by the teacher, who guides the students' reasoning and reflection. When reflection is done in a group, giving the opportunity to share, contrast and discuss ideas with classmates and the teacher in a relaxed atmosphere, the effects on learning are very significant.

When learners have to learn a new concept, it is important to assume that it is impossible to teach concepts "**by transmission**". Concepts are constructed in the learner's mind from the knowledge available in their long-term memory, i.e. their prior knowledge. In order for the learner to learn, we need to promote changes in the way learners build relationships between their knowledge and perhaps provide some new connectors (new data) to guide them in the construction of concepts. This construction implies a modification of existing connections, a "rewiring" that is not simple: it requires time, multiple opportunities and motivation on the part of the learners.

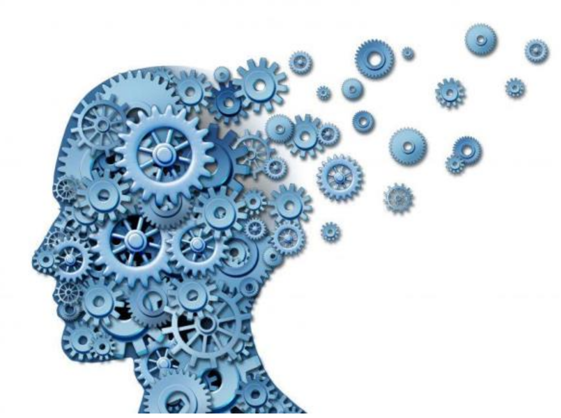
According to the cognitive theory of multimedia learning, the procedure we follow to learn is as follows: information is presented to us in words and images and is perceived by our senses, passing momentarily through our sensory memory (Mayer, 2008). If we pay attention to what is in this memory, the information passes to our working memory for further processing. It is in working memory that we mentally organise words to form a verbal model and we organise images to form a visual model, and then we integrate both models together to give them coherence; we also draw on our previous knowledge to integrate, with them, both models, always seeking coherence. This search for coherence is about making sense of what we learn so that it can pass into our long-term memory (from which we have retrieved prior knowledge); this is what is known as meaningful learning.

Therefore, for learning to take place, the three cognitive processes must be executed: selecting the relevant words/images (paying attention to them), organising them to obtain coherent mental representations and integrating these mental representations with each other and with previous knowledge. When all three processes are performed, we speak of active learning. For active learning to be stimulated and sustained, motivation is needed and metacognitive strategies need to be used appropriately.

Motivation can be based on several aspects: our interest in the subject matter, our self-efficacy beliefs, the attributions we make for academic success/failure, the goals we set for ourselves, and the perceived social cooperation of the learning environment. Metacognition refers to the knowledge of how we learn and the control we exercise as learners over our own learning process. Self-regulated learners possess metacognitive knowledge and metacognitive control, so teachers must help our students to become self-regulated learners.

The transformation of mental schemas that leads to the learning of new concepts is what researchers in cognitive psychology call conceptual change (Sousa, 2010). There are many forms of conceptual change, which are differentiated according to their degree of depth and their difficulty in occurring. Unfortunately, we teachers are often unaware of these levels of difficulty and, therefore, we may not adequately modify our teaching methods when faced with different cases.

Teachers often use teaching contexts that are very different from the contexts in which learning is applied, and we expect that what they learn in the classroom will have an impact on their performance in related situations, but in different contexts: we expect the learning they do to be transferable. Unfortunately, the problem is that, in the light of more than a century of research, it has become clear that transfer of learning does not occur as spontaneously as we might believe; on the contrary, transferring learning from one context to another is actually complicated and therefore infrequent.



In psychology, the term **working memory** is used to describe our ability to mentally and consciously hold and manipulate a limited amount of information for short periods of time. It is the mental space where we consciously perceive reality, where we remember, where we reason and where we imagine. Unfortunately, working memory is limited in several ways and can easily fail us when we need it most. To keep a piece of information in working memory, we cannot stop paying attention to it and avoid distractions. It is also a memory with limited space, so if we try to hold too much information, it overflows and the information is lost. Another limitation appears when performing activities that require a high mental process because the amount of space is reduced. It should also be mentioned that the working memory is very sensitive to stress and anxiety, emotional states that overwhelm it with thoughts that are unrelated to the task we wish to perform.

Taking into account the limitations of working memory is fundamental when it comes to promoting learning; it is the bottleneck that determines our ability to learn. One of the theories of how we learn with the most empirical evidence and practical application in the classroom is cognitive load theory, which is based on recognising the crucial role of working memory in learning and acknowledging its limitations: in order to learn it is important not to saturate working memory.

Higher cognitive skills such as reasoning, problem solving, critical analysis or creativity necessarily rely on a broad base of meaningful knowledge (Tokuhama-Espinosa, 2010). For such knowledge to be acquired, it must be knowledge that is comprehensible and transferable to multiple contexts, and this is achieved when learning is deep. To achieve this, teachers must provide opportunities for learners to use the learning. In a broad sense, learners develop meaningful knowledge when they use it to analyse and interpret situations, solve problems and create all kinds of solutions.

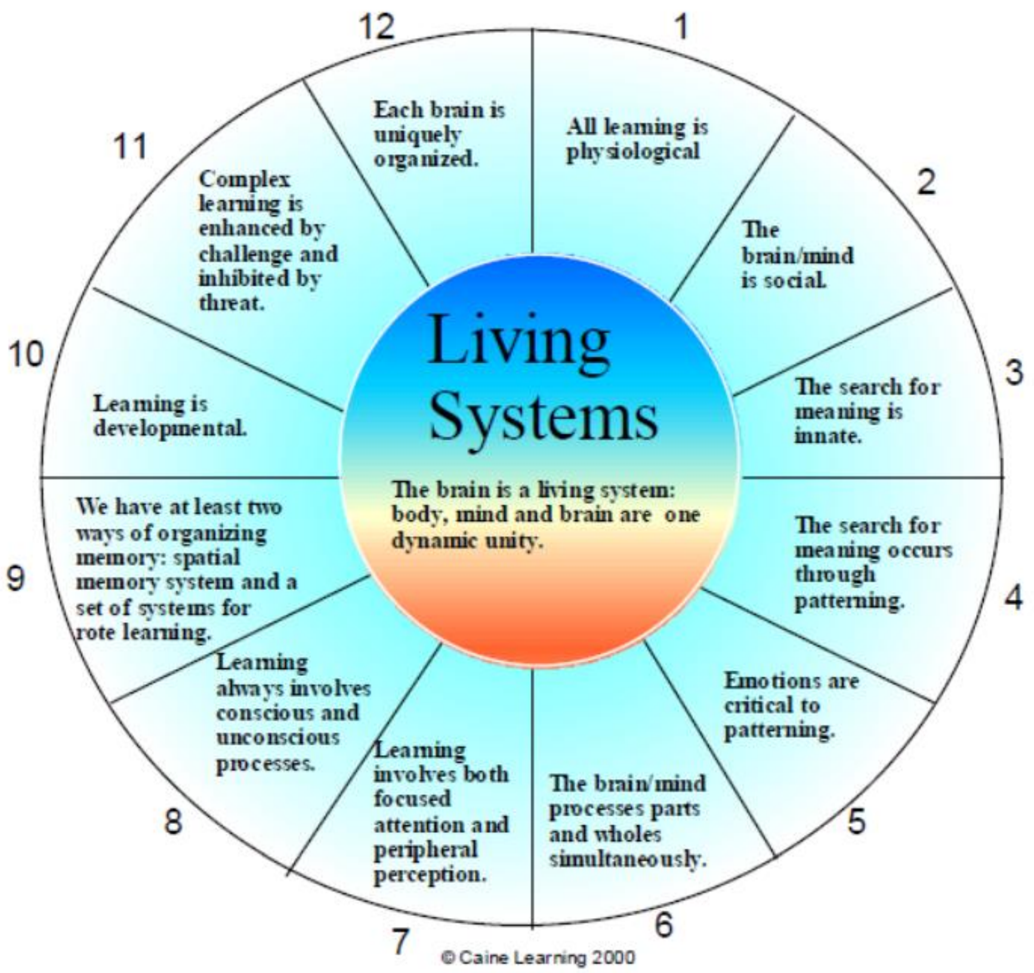
It is clear that what is indispensable for the development of meaningful knowledge is time. It is therefore important to reflect on the scope of educational objectives. In this sense, all the evidence points to the fact that it is better to opt for less extensive but more in-depth curricula than for extensive but superficial curricula that try to deal with a lot of knowledge but do not allow for its proper understanding. An important difference between deep and shallow learning lies in the ability of learners to transfer their new knowledge.

For further information about how the brain learns, check the additional resources:

- Weinstein, Y., Sumeracki, M., & Caviglioli, O. (2018). *Understanding how we learn: A visual guide*. Routledge.
- Slotnick, S. D. (2017). *Cognitive neuroscience of memory*. Cambridge University Press.
- Thomas, M. S., Mareschal, D., & Dumontheil, I. (Eds.). (2020). *Educational neuroscience: development across the life span*. Routledge.

5. Twelve general principles for classroom application

To conclude the chapter, based on Caine's et al. (2015) **twelve general principles of natural learning,** some guidelines for classroom action in the context of university teaching can be made as a conclusion.



1. **All learning is physiological**. Neuroscience has concluded that educational intervention causes physiological changes in the brain that affect both its structure and organisation. Brain structures involved in basic biological regulation are also part of behavioural regulation and are indispensable for the acquisition and normal function of cognitive processes.

University students are adults, with acquired habits of nutrition, exercise, relaxation, etc., and therefore have their own natural and individual rhythms and cycles. Action must therefore be taken in the direction of appropriate coordination of teaching in order to alter personal biorhythms as little as possible. Action can be taken at two levels: i) subject coordination - avoiding excessive workloads concentrated in time; and ii) curriculum coordination - so that the different subjects are coherent in the presentation of their learning objectives.

2. **The brain/mind is social**. The brain is modified by the interaction between multiple genetic factors, the environment and the surroundings, so that cognitive and affective stimulation by the environment plays a key role in human development.

It is essential to create a "social" climate in the classroom. In this sense, so-called "working groups" should be avoided and "group work" should be encouraged, i.e. the joint and changing cooperation of students should be promoted in order to prevent the formation of closed groups. On the other hand, participation in class should be encouraged. Social embarrassment" feeds student isolation, which the teacher should avoid at all costs. In those subjects where this is possible, practical work experience organised as "field trips" achieves both learning and social climate objectives.

3. **The search for meaning is innate in human beings**. Human beings possess what some authors have come to coin as the "sacred curiosity" to explore and sniff out what they do not know, in an attempt to clear the way to the truth. Numerous operations are integrated into the search: memory, perceptual, imaginative, inferential operations, so that all are geared towards creating new paths, i.e. inventing possibilities.

Organisational arrangements and teaching methods should provide the classroom with a safe and familiar environment. However, it should be borne in mind that the human brain has an underlying need to discover the unknown, which can be stifled if subjects are presented with closed content that does not require additional, personal input from the learner. University classes, therefore, should encourage interest in novelty, discovery and research, generating patterns of action in students that lead them to act on their own to investigate the broad spectrum of knowledge that surrounds each subject to combine enriching environments with complex challenges.

4. **The search for meaning occurs through patterning**. The human brain learns once it is able to organise information and categorise it. In the process of sorting, the brain tries to find meaning in order to draw patterns and resists forming these patterns if it does not find that meaning. Information with which the brain cannot form patterns, information without meaning, is isolated and partial information about something that does not make sense of the rest of the information and therefore remains in a peremptory state of rapid extinction.

Mental organisation can be promoted by an appropriate organisation of the subjects in the curriculum (curriculum coordination) and by a favourable organisation of the contents in each subject (subject coordination). It is important in all this that the learning-time binomial is taken into account in accordance with fundamental criteria of chronopedagogy. In addition, joint problem solving in the classroom should be encouraged, as well as the introduction of new concepts with a critical thinking approach.

5. **Emotions are critical to pattering**. Mental ordering, which is necessary for learning, is influenced by emotions, so that the brain makes classifications of information based on expectation, biases and biased judgements, degree of self-esteem and social interaction. Emotions and learning, therefore, cannot be separated.

The cognitive and affective domains of all human beings are intrinsically inseparable. It is important that each student feels real and effective support from teachers, school administrators and institutions. Teachers, for their part, must foster an adequate emotional climate in the classroom by using effective communication strategies that are close and that allow for a climate of dialogue and mutual respect and acceptance in order to develop day by day and at all times the processes of reflection and metacognition in each of the students, which are so important in their learning development. It is an objective of both the teacher and the university institution to gain the "trust" of their students and to avoid, through appropriate emotional pumping, ending up with "trusting" students who see their teachers and universities as the ultimate goal of their learning career.

6. **The brain is plastic.** Neuroscience has shown that the brain is an organ that is in continuous transformation; the internal structures of the brain are capable of transforming themselves according to the action demanded of them (neuroplasticity). A phenomenon that is simultaneous to the process of neuroplasticity is neurogenesis or the formation of new neurons from stem cells. Studies on brain plasticity show that from the experiences to which an individual is subjected, his or her neurons will develop more or fewer connections. Stimulation, experience, is therefore crucial for brain development.

It is essential that the neurogenesis time be respected as much as possible, so it is advisable for each subject to begin with content that helps students to achieve this "accommodation" of the brain. The first contents should not immediately deal with new concepts, but should start with a reminder of conceptual positioning and should state what the subject aims to cover, as well as introduce the new perspectives of reasoning that will be necessary.

7. **Learning involves both attention and peripheral perception.** The brain can absorb information of which it is aware and to which it pays attention. But it is also capable of absorbing information that

lies beyond its field of attention, i.e. peripheral stimuli. These stimuli, of complex origin, include both that which can be perceived without attention and that which, even with attention, cannot yet be perceived consciously.

Teaching materials play a very important role in learning. Peripheral perception is activated by the use of graphs, illustrations, strategy designs by means of concept maps, relating concepts to art or music, etc. The teacher's enthusiasm in the classroom and the environmental conditions of noise and temperature can significantly affect attention and thus the cognitive processes that lead to learning. The non-verbal language of communication is of great importance, as it can convey the teacher's emotions of passion for the subject.

8. **Learning involves both conscious and unconscious processes.** Many signals that are peripherally perceived by the senses enter the brain without the person's awareness and interact at unconscious levels. Unconscious processes are capable of some logical reasoning, much more so than generally believed, and this reasoning, once properly exercised through experience, can, when time is short, lead to advantageous conscious decisions.

Understanding that unconscious brain processes have a very important cognitive function, it seems obvious that fostering them is consequently positive. It does not seem obvious how to do this, but it is likely that with the support of an appropriate educational modality, as well as the help of ICT to encourage sensory memories, in addition to the fact of doing it in a climate of respect and opportunity, it can make the student activate this facet of unconsciousness and with it all the associated cognitive processes.

9. **Learning is fostered by the development of associative memory.** There are at least two types of memory: a spatial memory system that does not require repetition and allows immediate recall of experiences, and a set of systems for systematic recall that allows recall of isolated information; the more remote an item of information is from prior knowledge and experience, the greater the dependence of its recall on the systematic or repetition-based memory system.

Teaching that focuses on memorisation processes should be avoided. Memorisation is often useful and necessary, but it should be noted that memorisation-oriented teaching does not facilitate the transformation of information into learning and most likely interferes with the subsequent process of interpreting the surrounding world.

10. **Learning is a process**. As a process, it must follow orderly and progressive guidelines in which the brain must be given the necessary time to generate the appropriate brain structures through the

generation of relationships between the different information perceived and one's own life experience.

The intrinsic plasticity of the brain means that the timing of the complex learning process must be respected according to the criteria of chronopedagogy. These times can be optimised by teaching based on a relationship to one's own experience and to concepts already learned. The university represents an excellent opportunity for teachers to orientate their class development towards demonstration activities, project-based learning, field trips, viewing videos of experiences, experiments involving student interaction, etc. Successful teaching, therefore, depends on encouraging the use of all the senses to immerse the learner in a multitude of complex and interactive experiences. In this sense, the use of ICT in the classroom as a tool can be very important.

11. **Learning is positively influenced by challenging and negatively influenced by threatening environments.** The brain slows down in threatening situations, generating a feeling of helplessness that paralyses neurogenesis and greatly slows down learning processes. Negative stress, such as fear of evaluation or shyness, can generate negative threat effects. However, the brain learns optimally when it is correctly challenged in a positive way.

The student must perceive each subject as a learning opportunity. Therefore, both the teaching staff and the institution must provide a relaxed atmosphere for the student, free of threatening situations. It is important, in this sense, that the written tests represent, and are perceived by the students as such, new learning opportunities and not mere documents with the character of a qualifying test. Adequate time planning, as well as the coordination of the subject and the subjects in the curriculum, ensures that the student does not perceive the "opportunity" offered as a "threat".

12. **Every brain is unique**. Although all individuals possess the same set of systems, including the senses and basic emotions, the way they integrate and communicate with each other is unique to each individual. Furthermore, since neuroscience has shown that learning changes brain structure, it can be said that the more an individual learns, the more unique he or she becomes.

Teaching should be developed from a multi-faceted perspective, taking into account the visual, tactile, emotional and auditory preferences of each student, in order to appeal to their individual interests and enhance their optimal brain development. On the other hand, Special Educational Needs (SEN) is a very important aspect for the teacher to detect and consider.

The following indicators can help us to review whether our teaching design is conducive to learning from a neuropedagogical perspective.

	INDICATOR	YES	NO
1	The subjects in the curriculum are coordinated with each other (Princ. 1).		
2	The workload of each subject is distributed evenly over time (Princ. 1).		
3	The joint and changing cooperation of students is encouraged (Princ. 2).		
4	Interest in novelty, discovery and research is encouraged (Princ. 3).		
5	The organisation of the contents favours the creation of patterns and finding meaning in what is learned (Princ. 4).		
6	Effective and proximate communication strategies are used, allowing for a climate of dialogue and mutual respect (Princ. 5).		
7	The course begins with a review of prior knowledge in order to build on it (Princ. 6).		
8	Teaching materials activate peripheral perception (Princ. 7).		
9	The classroom environment and the teacher's non-verbal communication favour attention (Princ. 8).		
10	Understanding of content, rather than mere memorisation, is encouraged (Princ. 9).		
11	Different types of activities are carried out in order to encourage the use of all the senses (Princ. 10).		
12	Sufficient formative evaluation moments are offered (Princ. 11).		
13	Learning materials and activities are designed according to the guidelines of the UDL (Universal Design for Learning) (Princ. 12).		

Reflection assignment:
After answering yes or no to each of the above indicators, think about the following:
Indicators you answered no:

- Why do you think you do not work in this way?
- What internal and external factors make it difficult for you to plan your teaching according to this principle?

Indicators you answered yes:

- Do you collect evidence that your planning is achieving the expected results?
- Do you systematically monitor the results of your planning to help you improve what has not worked as you had hoped?

RESOURCES

- How baby brains develop https://youtu.be/R0fiu2S0_3M
- 2-Minute Neuroscience: Lobes and Landmarks of the Brain Surface (Lateral View) https://youtu.be/LQ4DlE1Xyd4
- 2-Minute Neuroscience: Cerebral Cortex https://youtu.be/7TK1LpjV5bI
- Cerebral cortex | Organ Systems | MCAT | Khan Academy https://youtu.be/mGxomKWfJXs
- Overview of the functions of the cerebral cortex https://youtu.be/X-m0JDCw6TE
- 2-Minute Neuroscience: Prefrontal Cortex https://youtu.be/i47_jiCsBMs
- Emotions: cerebral hemispheres and prefrontal cortex | MCAT | Khan Academy https://youtu.be/TQ51Gsb98ec
- Cerebellum | Organ Systems | MCAT | Khan Academy https://youtu.be/xf1okjCwdOg
- Hemispheric differences and hemispheric dominance https://youtu.be/X4IL333rppM
- 2-Minute Neuroscience: Wernicke's Area https://youtu.be/03Xtiz_ikw4
- 2-Minute Neuroscience: Broca's Area https://youtu.be/zIo_500V1LM
- Subcortical cerebrum | Organ Systems | MCAT | Khan Academy https://youtu.be/A_2f3onF3S8
- 2-Minute Neuroscience: Limbic System https://youtu.be/LNs9ruzoTmI
- Emotions: limbic system | Processing the Environment | MCAT | Khan Academy https://youtu.be/GDlDirzOSI8
- 2-Minute Neuroscience: Amygdala https://youtu.be/JVvMSwsOXPw
- 2-Minute Neuroscience: The Thalamus https://youtu.be/lF8_82e9RmQ
- 2-Minute Neuroscience: Nucleus Accumbens https://youtu.be/3_zgB19TE-M
- Introduction to neural cell types | Organ Systems | MCAT | Khan Academy https://youtu.be/L82bDTBMGUU
- 2-Minute Neuroscience: The Neuron https://youtu.be/6qS83wD29PY
- 2-Minute Neuroscience: Synaptic Transmission https://youtu.be/WhowH0kb7n0
- 2-Minute Neuroscience: Neurotransmitter Release https://youtu.be/FIIK2Gp5WzU
- Neurotransmitter anatomy | Organ Systems | MCAT | Khan Academy https://youtu.be/fYUpLvM5X7A
- 2-Minute Neuroscience: Mielin https://youtu.be/5V7RZwDpmXE
- 2-Minute Neuroscience: Action Potential https://youtu.be/W2hHt_PXe5o
- Neuroplasticity | Nervous system physiology | NCLEX-RN | Khan Academy

https://youtu.be/J8wW1t1JqUc

- The Nervous System https://www.interactive-biology.com/physiologyvideos/
- Neuroanatomy https://www.kenhub.com/en/start/neuroanatomy
- Modern ways of studying the brain | Organ Systems | MCAT | Khan Academy https://youtu.be/hCFtl4npukU

EVALUATION QUESTIONNAIRE

1. Fill in the blanks with the sciences referred to in the text:

"NEUROSCIENCE tries to understand how the nervous system works to produce and regulate emotions, thoughts and behaviours, as well as basic bodily functions, while NEUROPEDAGOGY aims to construct the educational process taking into account data on brain development, on effective methods of learning and teaching, on the organisation of the brain from the peculiarities of brain development of learners and educators.

2. Mark the disciplines that are related to neuropedagogy:

- Pharmacology.
- Psychology.
- Neurobiology.
- Physiology.
- Musicology.

3. True or false?

"Scientific advances in neuroscience have reached the general public, leading to the generation of pseudoscientific myths through the misrepresentation of findings. These myths have intruded into education and can lead teachers to make decisions in favour of practices that have no scientific backing". TRUE

4. Mark the statements that are false:

- Positive reinforcement has no impact on learning (this is a myth).
- Learning is best fixed when learners can make decisions and take part in assessment.
- Collaborative learning inhibits individual learning, which can hinder learners' progress by masking it.
- Negative emotions encourage learning to avoid them.

5. Fill in the gaps with the names of the lobes of the brain:

"The PARIETAL LOBULUS interprets sensations coming from the body and houses space recognition functions. The FRONTAL lobe is responsible for deciding the appropriate motor behaviour for each stimulus received by the brain. The TEMPORAL lobe is related to hearing, while the OCCIPITAL lobe is related to vision. The FRONTAL lobe houses important non-motor tasks such as planning behaviour, controlling our emotions, reasoning and judgement. The TEMPORAL lobe is home to important memory structures (hippocampus) and the unconscious emotional system (limbic system)".

6. True or false?

"It is a myth that in order to incorporate new knowledge, it must be connected to existing knowledge structures (prior knowledge) with which it has a semantic relationship. FALSE

1. Fill in the blanks with the sciences referred to in the text:

"NEUROSCIENCE tries to understand how the nervous system works to produce and regulate emotions, thoughts and behaviours, as well as basic bodily functions, while NEUROPEDAGOGY aims to construct the educational process taking into account data on brain development, on effective methods of learning and teaching, on the organisation of the brain from the peculiarities of brain development of learners and educators.

2. Mark the disciplines that are related to neuropedagogy:

- Pharmacology.
- Psychology.
- Neurobiology.
- Physiology.
- Musicology.

7. Complete the sentence:

"Any active learning experience must include activities that ensure that the learner..."

A. Is doing something.
B. Is motivated to learn.
C. Is thinking about what he learns.

8. Put in order the following phases that describe how the brain learns:

- 8. We draw on our prior knowledge to integrate verbal and visual models with it.
- 1. Information is presented to us in words and images and is perceived by the senses.
- 5. In working memory we organise images to form a visual model.
- 3. If attention is paid to sensory memory, the information is passed on to working memory.
- 4. In the working memory we mentally organise words to form a verbal model.
- 6. In the working memory, we integrate the two models with each other to make them coherent.
- 7. What we learn goes into our long-term memory.
- 2. The information passes momentarily through the sensory memory.

9. Complete the sentence:

"The transformation of mental schemas that leads to the learning of new concepts is what researchers in cognitive psychology call CONCEPTUAL CHANGE. There are many forms of CONCEPTUAL CHANGE, which are differentiated according to their degree of depth and their difficulty in occurring. Unfortunately, we teachers are often unaware of these levels of difficulty and, therefore, we may not adequately modify our teaching methods when faced with different cases."

- Metacognitive control
- Conceptual change

1. Fill in the blanks with the sciences referred to in the text: "NEUROSCIENCE tries to understand how the nervous system works to produce and regulate emotions, thoughts and behaviours, as well as basic bodily functions, while NEUROPEDAGOGY aims to construct the educational process taking into account data on brain development, on effective methods of learning and teaching, on the organisation of the brain from the peculiarities of brain development of learners and educators.
2. Mark the disciplines that are related to neuropedagogy: ● Pharmacology. ● Psychology. ● Neurobiology. ● Physiology. ● Musicology.
● Neurological connections
10. True or false? "Higher cognitive skills such as reasoning, problem solving, critical analysis and creativity do not require significant knowledge or deep learning. FALSE

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