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CHAPTER 49

A neuroscientific approach to the importance of emotions for the meaningful learning process

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ABSTRACT

This article investigated the intersection between Neuroscience and Education, highlighting important contributions to the understanding and improvement of the learning process. Highlighting the importance of emotions in the educational process, from a neuroscientific perspective. Initially, we discuss David Ausubel's theory of meaningful learning, emphasizing the importance of motivation and emotions in the consolidation of knowledge. Next, we explore the emerging field of Neuroeducation, which seeks to translate neuroscientific findings into concrete educational practices. The relevance of neuroplasticity was addressed, showing how the brain adapts and reorganizes itself in response to stimuli and experiences, directly influencing learning. In addition, we examine the role of emotions in cognition, highlighting their fundamental interconnectedness and their impact on the effectiveness of the educational process. The research aims to contribute to the discussion of how emotions influence and interact with the way we learn, and to highlight how they are intrinsically linked to the process of meaningful learning. The study used the bibliographic methodology, and is developed with the literature review of Casassus and Morim (2009); Santos (2000); Goleman (1995); Ausubel (1978); Cosenza (2011) and Fonseca (2002). Finally, in the final considerations, we emphasize that although the findings of Neuroscience offer valuable insights, there is no universal approach to pedagogical practice, highlighting the need to consider individual diversity and the interaction between emotion and cognition to promote more meaningful and motivating learning.

Keywords: Neuroeducation, Emotions, Meaningful Learning.

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INTRODUCTION

The learning process is fundamental to define and influence our behaviors in relation to the world and our interaction with the environment that surrounds us, since it is related to the acquisition of new information, which, in turn, leads to behavioral changes (Mourão Júnior; Melo, 2011). According to Neuroscience, this information should trigger neurochemical processes and transformations in our brain, reinforcing and/or creating connections between neurons – synapses – thus ensuring the consolidation of knowledge in long-term memory, thus promoting the phenomenon of learning.

This work presents a neuroscientific approach to the importance of emotions for the learning process, presenting some contributions of Neuroscience to the understanding of the cognitive activities involved in this process. The research establishes a dialogue between learning, brain and emotion, based on David Ausubel's theory (1978, 2003) on meaningful learning, as well as on studies in the area of Neuroeducation (Cosenza; Guerra, 2011), which provide us with a scientific basis for how the brain learns. Thus, the guiding question of this research is: "How can the discoveries of Neuroscience in relation to emotions contribute to the learning process?"

The general objective of this work is to show how emotions are articulated with the process of meaningful learning, while the specific objectives are to categorize emotions and relate them to the motivation to learn, in addition to identifying which emotions may be involved in the educational process.

Neuroscience does not prescribe pedagogical methods. Instead, it offers *insights* into how the brain can activate different sets of interconnected neurons to perform cognitive functions important for learning to occur. However, according to Ausubel (2003), all this brain processing will only occur in the cognitive structure of the learner if he or she is motivated to learn in a meaningful way, because it is through motivation that the learner develops attention, selects information and assigns meaning to it. It is because of this motivation that it is necessary to relate emotions to learning.

This study follows a bibliographic approach, as defined by Fonseca (2002), which involves the review of theoretical references published in various media, such as books, scientific articles and websites. The bibliographic research is complemented by an interdisciplinary approach of articulation and interrelation (Pombo, 2005), seeking to integrate contributions from Neuroscience, Psychology of Learning and emotions.

The stages of the research included theoretical training on the subject, followed by an interdisciplinary literature review. Information was collected from various sources, including annals, books, magazines, scientific journals, focusing on discussions and studies on the contributions of Neuroscience to the learning process and its relationship with emotions.

The analysis of the collected information was carried out in the light of several theoretical conceptions, covering fields such as Psychology, Pedagogy and Sociology. Authors such as Casassus (2009), Morin (2011), Santos (2000) and Goleman (1995) highlight the intrinsic relationship between emotion and learning, the need to integrate affectivity and emotion in the educational process and the fundamental role of emotions in teaching and learning. The entire interdisciplinary survey is interpreted in the light of David Ausubel's theory of meaningful learning (1978, 2003), as well as Neuroeducation, as discussed by Cosenza and Guerra (2011), and the importance of emotions in learning emphasized by Fonseca (2002).

EMOTIONS

Neuroscience has presented evidence of how emotions affect the brain and, in turn, the learning process. When individuals experience emotions such as joy, fear, or anxiety, different regions of the brain are activated, including the prefrontal cortex, limbic system, and brain amygdala. These areas are involved in the regulation of emotions, decision-making, and memory. The brain's amygdala, a very important structure of our emotional activity in particular, is closely linked to the hippocampus, which is crucial for the formation of memories. Therefore, emotions have a direct connection to learning, since the structure involved in emotions has a strong connection to the structure responsible for the formation of long-term memories. Therefore, the triggering of emotions also contributes to the formation of memories. Cosenza and Guerra (2011) describe the sequence of these processes:

> The sense organs send the relevant information to the brain through neuronal circuits. If an important stimulus, with emotional value, is captured, it can mobilize attention and reach the specific cortical regions, where it is perceived and identified, becoming conscious. The information is then directed to the brain's amygdala. The amygdala is usually included in a set of brain structures known as the limbic system, which is credited with controlling emotions and motivational processes. It is a cluster of neurons of complex organization that has multiple connections with other areas of the nervous system. Through these connections, the amygdala acts as a coordinating center. (Cosenza; Guerra, 2011, p.76-77)

Emotions can substantially influence the learning process, both positively (when the learner is motivated and experiences positive valence emotions, such as joy, interest, gratitude, and hope) and negatively (when the learner is sad, angry, or moody). However, emotion and cognition are intrinsically linked, working together to ensure learning. In this context, emotions emerge as essential components of cognition, contributing to intellectual development, memory, language, decision-making, reasoning, and learning. Fonseca (2016, p.370) ponders:

> Emotion directs, conducts and guides cognition, and one cannot understand learning without recognizing its role in such an important human adaptive function. The interdependence of emotion and cognition in the brain is demonstrated by the new technologies of imaging our organ of learning and social interaction.

Therefore, emotions are inseparable parts of the learning process, a finding reinforced by several recent studies in areas such as Neuroeducation and Psychopedagogy, showing that emotions, when related to motivation, have a fundamental impact on learning (Chart 1). Fonseca (2016, p.371) says that "emotion guides attention and this, in turn, guides memory and learning."

Table 1 – Classification of emotions by groups of emotions and motivations.

Emotion	**Motivation for learning**
Joy/Happiness	It increases intrinsic motivation, makes learning more pleasurable and rewarding. (Morin; 2011)
Interest/Curiosity	They are powerful engines for the pursuit of knowledge, leading students to dedicate themselves more and deeply explore topics of interest. (Gruber; 2019)
Pride/Satisfaction	It reinforces self-esteem and motivation to achieve new goals and academic challenges. (Abrantes; 2012)
Fear/Apprehension	In moderate doses, it can push students to try harder and be better prepared to face academic challenges. In excess, it can cause anxiety and despair. (Lent; 2010)
Frustration/Challenge	It can motivate students to persist in the face of challenges, seeking new strategies, and developing additional skills. (Fonseca; 2016)
Curiosity/Ambiguity	It motivates students to seek answers, explore new concepts, and develop a deeper understanding of the subject. (Fonseca; 2016)
Helplessness/Hopelessness	It significantly undermines student motivation, leading to apathy and a lack of interest in school. It's important to offer emotional support and coping strategies. (Fonseca; 2016)
Empathy/Compassion	It motivates students to engage in activities that promote collective well-being and group collaboration. (Ausubel, 1968; 2003).

Source: The author.

In the context of learning, the activation of these emotions can influence learners' motivation and engagement. For example, positive emotions such as curiosity and enthusiasm are associated with a greater release of dopamine in the brain, which can increase motivation and desire to learn (Cosenza; Guerra, 2011). Fonseca (2016) highlights the importance of promoting emotionally positive experiences to create a stimulating learning environment.

Neuroscience also demonstrates how emotions affect attention and concentration during learning. Intense emotions, both positive and negative, can capture learners' attention, directing it to relevant stimuli in the learning environment (Carvalho *et al*; 2019). However, negative emotions, such as fear or anxiety, can distract from learning objectives, impairing concentration (Lent; 2010). Fonseca (2016) emphasizes the importance of creating a safe and threat-free learning environment to minimize the negative impact of emotions on learners' attention.

Therefore, neuroscience explores emotional regulation and its role in promoting a positive and productive learning environment (Paxiúba; 2019). Emotion regulation strategies, such as emotional expression, problem-solving, and social support, can help learners cope with intense

emotions and maintain an emotional state suitable for learning. Fonseca (2016) highlights the importance of educators being attentive to the emotional needs of learners and providing effective emotional support to promote a healthy and welcoming learning environment.

The integration of Neuroscience concepts and the ideas of Fonseca (2016) highlights the complexity of the relationship between emotions and learning, emphasizing the importance of educational approaches that are sensitive to learners' emotions to promote effective and meaningful learning. As stated by Carvalho *et al.* (2019, p. 9), "it is already known that the greater the emotional charge, the higher the level of stored content, so what we need is to practice more positive emotions (enthusiasm, curiosity, involvement, challenge), while negative ones (anxiety, apathy, fear, frustration) should be avoided."

THEORY OF MEANINGFUL LEARNING

David Ausubel's theory of meaningful learning consists of attributing meanings to a new content that is being learned, based on previous knowledge existing in the cognitive structure of the learner. According to Ausubel (1980, 2000), the single most important factor influencing learning is what the learner already knows, taking into account his or her previous knowledge. In the words of Postman and Weingartner (1969):

> We can, in the end, learn only from what we already know. Contrary to common sense, this means that if we don't know much, our capacity to learn isn't very great. This idea – in itself – implies a major shift in most of the metaphors that drive school policies and procedures. (Postmam; Weingartner, 1969, p. 62)

Thus, meaningful learning occurs when new concepts, ideas, or propositions interact with other relevant knowledge that the learner already possesses (which Ausubel calls subsumers) and are anchored by them. It is in this process of anchoring, called assimilation, that "new knowledge acquires meanings and prior knowledge acquires new meanings. In this interaction, the two change." (Moreira, 2012, p. 10).

In the theory of meaningful learning, learning begins from the student's previous knowledge, the context in which he is inserted and what he already knows. The greater the relationship between their previous knowledge and the contents covered in the classroom, the more significant and efficient their learning will be, because, according to Ausubel (1968; 2003), the more one knows, the more one learns. In addition, meaningful learning is progressive, that is, meanings are progressively captured and internalized and, in this process, language and personal interaction are very important. (Moreira, Caballero and Rodriguez Palmero, 2004). Therefore, it is important that teaching always starts from what the student already knows, because it is through this path that the contents to be

learned will be potentially significant and, in this way, will reveal how to identify each of the difficulties faced by the learner.

In this process, the new knowledge acquires meaning for the learner and the previous knowledge becomes richer, more differentiated, more elaborated in terms of meanings, acquiring more stability. (Moreira and Masini, 1982, 2006; Moreira, 1999, 2000, 2006; Masini and Moreira, 2008; Valadares and Moreira, 2009). It is also important to highlight that, according to Nóbrega (2023, p.31),

> For Ausubel (1963; 1966; 1968), meaningful learning is a non-arbitrary and substantive process. Not arbitrary because the new information relates logically, clearly, and explicitly to the subsumptive concept. And it is substantive because "it is the 'substance', the 'stuffing' of the concept that is learned and not just a name and (or) a statement without any meaning for the learner." (Valadares, 2011, p.37).

For Ausubel (1968; 2003), our brain organizes information/ideas in a conceptually hierarchical way, that is, more general information/ideas assimilate more specific ones, in such a way that our cognitive structure is nothing more than "a hierarchical structure of concepts that are representations of the individual's sensory experiences." (Moreira, 1999, p. 153). It can be seen that through prior knowledge, Ausubel (1968; 2003) defines the concept of subsumer as a set of specific pre-existing knowledge in the learner's cognitive structure. The lack of adequate subsumers to anchor new knowledge causes it to be arbitrarily scattered in the cognitive structure of the individual who learns. Moreira and Masini (2001, p. 17-18) show that,

> For Ausubel, meaningful learning is a process by which new information relates to a relevant aspect of the individual's knowledge structure. Meaningful learning occurs when new information is anchored in pre-existing relevant subsumers in the learner's cognitive structure. This process of anchoring in the new information results in growth and modification of the subsumptive concept.

In short, meaningful learning is learning with meaning, understanding, meaning; which depends essentially on the learner's prior knowledge, the relevance of the new knowledge, and his or her predisposition to learn. This predisposition implies an intentionality on the part of the learner. This, in turn, depends on the relevance that the learner attributes to the new knowledge (Rodriguez Palmero *et al.*, 2008) as well as their motivation to learn meaningfully.

David Ausubel's theory of meaningful learning emphasizes the importance of connecting new knowledge to previous concepts already existing in the learner's mind. In this context, motivation plays a crucial role, as it is the impulse that drives the learner to actively seek this connection between information. Emotions, in their amplitude, involve positive and negative, conscious and unconscious behavioral aspects, and are semantically linked to other expressions, such as affectivity, interpersonal intelligence, emotional intelligence, social cognition, motivation, conaction,

temperament and personality of the individual (Fonseca, 2016). These elements are extremely relevant in learning and social interactions.

When the learner feels motivated, this motivation plays a key role in meaningful learning. Genuine interest and curiosity in the subject motivates learners to actively and persistently engage in the learning process. However, it is important to recognize that motivation can be influenced by external and emotional factors, as highlighted by Ausubel (1968; 2003). In an encouraging and emotionally positive learning environment, where learners feel safe to express their ideas and feelings, motivation is more easily sustained. In contrast, negative emotions can impair learners' motivation and make it difficult to construct meaning.

It is essential, therefore, to promote a learning environment that stimulates learners' motivation and minimizes negative emotions that may interfere with the process. This can be achieved by creating educational activities and materials that are meaningful to students, while also encouraging an environment of support, collaboration, and appreciation of each other's individual experiences. In addition, the consideration and importance of prior knowledge cannot be overemphasized, because "from them the student will interact with the new knowledge received in such a way as to elaborate meanings so that both the previous knowledge and the new knowledge make more sense to him." (Nóbrega; 2023, p.32). This approach allows not only to promote meaningful learning, but also to cultivate a healthy educational environment conducive to the integral development of students.

NEUROEDUCATION

Neuroeducation, as defined by Cosenza and Guerra (2011), is a field that unites studies on the brain (Neuroscience) and educational practice. The goal of this area of research is to better understand how the brain works during learning, in order to develop more effective teaching strategies. Neuroeducation connects what we know about the brain and how people learn. Understanding brain functioning during learning can inform pedagogical practices that promote more meaningful and efficient learning. "If behaviors depend on the brain, the acquisition of new behaviors, an important goal of education, also results from processes that occur in the learner's brain." (Cosenza; Guerra, 2011, p.140)

Neuroeducation transcends the theoretical sphere, focusing on translating neuroscientific research into concrete educational practices. This transmutation may include, for example, training programs for educators, the development of teaching materials based on scientific evidence, and the configuration of learning environments conducive to brain development. In essence, it is about employing knowledge about the human brain to facilitate and enrich the learning process of students in a more efficient and meaningful way (Cosenza & Guerra, 2011).

It is common for educators to associate students' learning difficulties with neurological disorders. This implies that, in the face of obstacles in the comprehension or assimilation of the content, these professionals tend to assume that these obstacles result from dysfunctions in the brain functioning of the learners. However, as noted by Cosenza and Guerra (2011), there was, to some extent, a gap in the clear understanding of how the normal learning process occurs in the brain. This finding suggests that, although educators readily attributed learning disabilities to neurological issues, there was no solid understanding of the brain structures involved in this process, nor of their specific properties and functions. Understanding brain functioning in the context of learning is essential to inform more effective pedagogical practices.

The advancement of neuroscientific knowledge in recent decades has been fostered, to a large extent, by the transdisciplinary perspective. In this sense, the integration of *insights* from neurosciences with education promises to support more effective approaches to address school difficulties and improve the quality of teaching. However, it is crucial to emphasize that neurosciences applied to education do not aim to institute a new pedagogy or offer definitive solutions to educational challenges. Instead, they provide a solid foundation for improving existing pedagogical practices and suggesting more effective interventions, based on a detailed understanding of the cognitive processes underlying learning.

> It is stated that the progress of knowledge in this millennium will only be possible from a transdisciplinary perspective. Through this perspective, the various areas of knowledge will use their assumptions to advance towards new knowledge. In this approach, we believe that education could benefit from neuroscientific knowledge to address school difficulties and their corrective interventions. This would make it possible to explore the potential of the nervous system in a creative and autonomous way and also to suggest significant interventions to improve school learning and quality of life. (Cosenza; Guerra, 2011, p.145)

By acknowledging that teaching strategies that take into account the functioning of the brain tend to be more efficient, the discoveries and advances in neuroscience enable a more scientific approach to the teaching-learning process, and not just based on intuition or tradition. In summary, neurosciences can significantly enrich our understanding and practice of education, providing a solid foundation for improving learning.

> (...) It is important to clarify that they do not propose a new pedagogy or promise definitive solutions to learning difficulties. They can, however, collaborate to substantiate pedagogical practices that are already successfully carried out and suggest ideas for interventions, demonstrating that pedagogical strategies that respect the way the brain works tend to be more efficient. Advances in neuroscience enable a more scientific approach to the teaching-learning process, based on an understanding of the cognitive processes involved (COSENZA; GUERRA, 2011, p. 142-143).

It is critical to recognize that while the contributions of neuroscience are significant, the responsibility for approaching teaching and learning rests with educators. The understanding of brain

functioning can improve pedagogical practices in the classroom, making them more effective (Carvalho *et al.*, 2019). Neuroscience, which investigates the human brain at a molecular, cellular, and systemic level, offers educators *insights* into how the brain processes information, stores memories, and develops cognitive abilities. Thus, the integration between neuroscience and learning processes has the potential to promote significant advances in educational practice, contributing to making the learning process more effective and engaging.

NEUROPLASTICITY

Neuroplasticity plays a crucial role in the learning process. It is the brain's ability to adapt and reorganize itself in response to new experiences, stimuli, and demands. During the acquisition of new knowledge, skills, or concepts, the brain undergoes physical and structural changes to integrate this new information. A fundamental aspect of neuroplasticity is the formation of synapses, the connections between neurons, which strengthen during learning, facilitating the transmission of electrical signals between neuronal cells that make up the structure of the network of cells that deal with that specific information. This dynamic is crucial for the consolidation of memory and the acquisition of new learning. As highlighted by Cosenza and Guerra (2011, p.33), "the formation of new synaptic connections between cells in the nervous system is fundamental for the development of new functional capacities".

In addition, neuroplasticity involves the brain's ability to reorganize itself structurally. This means that neural networks can be reshaped in response to changes in cognitive demands. For example, when we are learning a new language, areas of the brain responsible for language can reorganize themselves to accommodate this new ability, that is, when we learn, our brain literally changes, not only in cognitive aspects and abilities, but in its morphological and physiological structure. As pointed out by Cosenza and Guerra (2011, p.34-35),

> However, there are capabilities that seem to depend on a more specific interaction with the environment, such as spoken language, for example. In fact, this is a capacity already programmed into our nervous system. Children with normal brains will learn to speak and understand language in a natural way, without the need to be taught. However, which language they will master depends on their social interaction. There are indications that, at birth, children are already selective to the sounds of the mother tongue. Therefore, some learning seems to occur in the intrauterine period.

Neuroplasticity also allows the brain to adapt to the individual needs of learners. Each person has a unique profile of brain plasticity, meaning that some can learn more quickly in certain areas than others (Cosenza; Guerra, 2011). This highlights the importance of nuanced educational approaches that recognize and address the different learning needs of students. "Training and learning can lead to the creation of new synapses and the facilitation of the flow of information within a nerve circuit." (Cosenza; Guerra, 2011, p.36) Another important aspect is the role of

environmental stimulus and experience in neuroplasticity. In this regard, Cosenza and Guerra (2011, p.34) state that "enriched environments, which offer a variety of stimuli and cognitive challenges, can promote brain plasticity, facilitating the learning process." On the other hand, the lack of stimulation can result in less plasticity and, consequently, learning difficulties.

The plastic capacity of our brain allows for lifelong learning. Their continued ability to adapt and change suggests that it is never too late to learn and develop new skills, even in adulthood. This highlights the importance of lifelong learning programmes and the promotion of a culture of continuous learning. Cosenza and Guerra (2011, p.35) believe that

> The adult brain does not have the same facility to promote such great modification, and for a long time it was believed that the capacity for learning was small in adults and almost null in old age. Current knowledge allows us to affirm that nervous plasticity, although diminished, remains for life; therefore, the ability to learn is maintained.

Neuroplasticity is a core concept that permeates all facets of the learning process. "Learning is a consequence of facilitating the passage of information along synapses." (Cosenza; Guerra, 2011, p.38). It highlights the brain's incredible ability to adapt, change, and grow in response to experiences and stimuli, providing a foundational foundation for human development and lifelong learning.

> In short, from a neurobiological point of view, learning translates into the formation and consolidation of connections between nerve cells. It is the result of chemical and structural modifications in the nervous system of each one, which require energy and time to manifest themselves. Teachers can facilitate the process, but ultimately learning is an individual and private phenomenon and will obey the historical circumstances of each of us [...] Learning and behavioral change have a biological correlate, which is the formation and consolidation of synaptic connections between nerve cells (COSENZA; GUERRA, 2011, p.38-39).

Therefore, understanding neuroplasticity implies the need for educational approaches that recognize and harness the brain's ability to adapt and change. Cosenza and Guerra (2011) emphasize the importance of promoting flexible, adaptive, and meaningful learning to facilitate the teaching and learning process.

FINAL THOUGHTS

Findings from the neurosciences may offer some useful suggestions for the educational field, although there is no universal approach applicable to all educational contexts. This is due to the fact that each individual is unique and subject to diverse influences, both in their family and social environment. However, neuroscientific knowledge provides an enriching dialogue with educational practice. Through the knowledge derived from neurosciences, it is possible to propose evidence-based interventions, highlighting the effectiveness of educational approaches that consider the principles of brain functioning.

Genuinely meaningful and motivating learning emerges from the interaction between emotional and cognitive processes. These two aspects are intrinsically intertwined at a fundamental neurofunctional level, so dysfunction in one of them can significantly affect the other, as evidenced by Fonseca (2016). Therefore, it is recognized that emotions play a central role in the learning process, and can both enhance and hinder it.

Understanding the workings of the human brain reveals the crucial importance of emotions in human development. They have the power to catalyze the learning process, giving it greater engagement, significance, and memorability. However, it is imperative to also recognize that emotions can inhibit learning if they are not properly managed and channeled.

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