



CONTRIBUTIONS OF NEUROSCIENCES TO EDUCATION AND LEARNING: OUTLINING CONCEPTS AND PRACTICES



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ABSTRACT

Introduction: The study sought to show how knowledge and understanding of the brain mechanisms involved in cognition makes it possible to more effectively guide the choice of more appropriate actions, the effect of which is learning. Objective: to highlight some contributions of theoretical-scientific knowledge about the contributions of neurosciences to the educational field and to the practices that occur in it. Methods: we opted for descriptive qualitative research, with a view to investigating the proposed theme, through a literature review and a qualitative descriptive approach, so that the study was based on qualitative data about the object analyzed, with the objective of raising debates and interpretations. In this sense, we sought the theoretical framework of scholars on the subject, such as Izquierdo, Lent, Guerra, Herculano-Houzel and Relvas, as an example. Results: it revealed a vision of how the human brain learns and how one can take advantage of this knowledge in the learning process. Conclusion: the study made it possible to reach results about human learning from the cognitivist perspective, and it is of fundamental importance to know the functioning of the brain for effective and meaningful learning.

Keywords: Education. Neuroscience. Apprenticeship.

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INTRODUCTION

The central theme of this research concerns the relationship between neurosciences and education, in the light of contemporary theories of learning, and it is important to know the functioning of the brain during the teaching and learning process. Without losing sight of the fact that learning is possibly an important process that all human beings go through, in such a way that it can be said that practically everything that men and women do needs to be understood by others, this research addresses some approximations between neurosciences, more specifically, cognitive neuroscience, and Piaget's theory of learning, which points out that the environment is an important factor in the process of acquiring learning by human beings (LEFRANÇOIS, 2008). Shedding light on the development of more effective pedagogical practices, which take into account the functioning of the brain and the influence of the environment on cognitive development, as pointed out by authors such as Rosa (2014) and Guerra (2011).

In this line of interpretation, this study aims to highlight the issues related to cognitive neuroscience and the neuroscientific bases of learning, based on the theoretical reflection of some authors of the technical literature in the area. It is worth emphasizing that this reflection on a new knowledge based on neuroscientific knowledge directed to human learning is important due to the possibility of understanding how people organize their cognitive processes, as well as recognizing the differences between these organizations, as exposed by Silva and Bezerra (2011), Lent (2019) and Relvas (2014). In this way, in order to delimit the scope of the investigation, the study tried to show that "the deepening of what neuroscience is allows the understanding that the learning process takes place in the brain" (RELVAS, 2014, p. 146).

METHODS

It is important to consider that the approach of descriptive qualitative research was chosen², through a bibliographic review on the theme concerning neuroscience applied to education and learning, and it is of fundamental importance to know the functioning of the brain for effective and meaningful learning. To elucidate these issues, a theoretical framework was sought through bibliographic material related to this theme. In view of this, it was observed the importance of choosing research procedures related to qualitative research and organizing research data that are aligned with the theoretical assumptions analyzed. In this way, the use of a *documentary corpus*, composed of articles, books and

² Qualitative research is understood to be that which favors the analysis of microprocesses, through the study of individual and group social actions, carrying out an intensive and analytical examination of the collected data (MARTINS, 2004, p. 1).

theses, corroborated, therefore, an interpretative approach that sought to be based on descriptive data.

In this horizon, the interlocutions between neuroscience and cognitive psychology stand out, with an interdisciplinary approach, having as some of the main authors used in this research, theorists such as Lent (2010; 2019), Cosenza and Guerra (2011), Herculano-Houzel (2010; 2017), Relvas (2005; 2014) and Izquierdo (2004; 2010), as an example. From this perspective, in the light of the different currents of thought studied, it is worth noting that all the relevant points of view found in the specialized literature on the subject were considered. Thus, because this study does not intend to exhaust the possibilities of discussion on the subject, some points were highlighted and aspects considered relevant about this theme were raised, which allowed us to reach results and conclusions that can be used for further study in future research.

RESULTS

In the particular case of this study, it is worth pointing out that, as neuroscience allows the understanding of the processes that occur in the brain³, a creative dialogue between cognitive neuroscience and education is necessary, because when we learn about the brain, we prepare ourselves for the process of building knowledge and the world (RATEY, 2001). This is especially because, currently, "neuroscience already has a solid set of scientific evidence that can contribute to the field of education" (AMARAL and GUERRA, 2002, p. 15).

In this sphere, as Cosenza and Guerra (2011) point out, neuroscience has brought important contributions with regard to the knowledge of the biological bases of learning, influencing the activity of the teacher in his teaching process. For the authors, therefore, learning and education are linked to brain development, in which new synapses are activated in response to environmental stimuli. It is important to consider that, according to Lent (2019), "among the various disciplines that can establish links with the problems of education, perhaps the one with the greatest potential for conceptual and practical repercussion is neuroscience" (p. 7).

Considering the issues exposed about these conceptions that are now unveiled, it is worth noting that this multidisciplinary field allows the understanding that a stimulus generates new information, reaching the brain through the synaptic connections between one neuron and another, based on pre-fixed memories, making learning have a greater

³ Neuroscience is a natural science that investigates, describes and interprets data and discovers the principles of brain structure and functioning, providing an understanding of the mental processes and behaviors observed (AMARAL and GUERRA, 2002, p. 47).



basis and meaning. given that, in light of the theoretical contributions of Amaral and Guerra (2022), " neuroscience enables a more scientific approach to teaching and learning processes" (p. 47).

From this perspective, it is important to consider that educational neuroscience "develops research and addresses themes and issues that are related to learning and possible contributions to education" (AMARAL and GUERRA, 2022, p. 41). Furthermore, it should be noted that, for these aforementioned authors, before the advance of neuroscientific research, the only way to understand the processes of development and learning was purely "through the observation of human behavior and its relationship with the environment" (p. 43).

In view of this, according to Relvas (2014), "knowledge about neuroscience can help to identify each individual as unique and also to discover the regularity, development and time of each one" (p. 201), since each individual is unique and singular, having their own pace and time of learning. In this dynamic, in order to scrutinize these conceptual issues under analysis, it is worth underlining the important contribution that neuroscience has made to the

it is the modern scientific discipline that begins at the end of the nineteenth century by the confluence of several so-called basic disciplines: anatomy, histology, biochemistry, molecular biology, with many other so-called professional (or "clinical") disciplines, neurology, neuropathology, psychology, and psychiatry. To these were added artificial intelligence, robotic informatics, various branches of mathematics and physics (HERCULANO-HOUZEL, 2010, p.18).

From this theoretical and analytical basis, it is urgent to emphasize that neuroscience, in contemporary times, has been standing out in the areas of interdisciplinary research. To this extent, for Consenza and Guerra (2011, p. 143), neurosciences are natural sciences that study principles that describe neural structure and functioning, seeking to understand the observed phenomena. In this sense, in the educational field, the focus of study is mental functions, that is, the functioning of the human brain, contributing significantly to the learning process.

According to this argument, Herculano-Houzel (2010) points out that learning is related to the modification of the brain by virtue of experience, that is, it corresponds to the brain's ability to modify itself in such a way that it starts to act in a different way according to its previous experience. Regarding this conception, the word learning, according to Lent (2019), "involves an individual with their brain, capturing information from the environment, storing it for some time and, eventually, using it to guide their subsequent behavior" (p. 13).

From this theoretical basis, it is unavoidable to understand that neuroscience studies have neurons and their constituent molecules at their core, as well as the organs of the nervous system and their specific functions, as well as cognitive functions and the resulting human behavior, as observed in the studies of Kandel, Schwartz and Jessel (2003). In fact, neuroscience is currently experiencing a process of great scientific discoveries⁴ and mass communication networks allow this knowledge to be disseminated to the entire population and even expanded through studies by other researchers.

In the light of Guerra's (2011) perspective of analysis, it is important to emphasize that this knowledge can allow the establishment and strengthening of learning and the consolidation of synaptic connections in neuronal circuits through stimulation and understanding of the brain's functionalities. Still, there are questions to be answered by further research on the brain, given its importance and complexity. Therefore, as a background to this context, the definition of neuroscience stands out, an area in constant updating, as the set of disciplines that study the nervous system and the relationship between brain and mental functions, through various methods, as stated by Herculano-Houzel (2010).

According to the author in question, the history of neuroscience dates back to its first experiments 2500 years ago (B.C.). when the trepanation technique was used, which consists of opening holes in the skull, a surgical procedure to treat disorders such as epilepsy, going through the history of humanity to the present day, when scientists were able to reproduce neural patterns from one person to another, having been the first direct transmission of "thoughts" between two human beings (HERCULANO-HOUZEL, 2010).

It should also be noted, from the perspective of Firmino and Braz (2020), that neuroscience contemplates other sciences expanding information and building knowledge that does not seem to be exhausted. This science brings together three areas, neuropsychology, neuroanatomy and neurophysiology, seeking to understand behavior and its functions, as well as explain the underlying physiological mechanisms. Neuroscience has been built in the scientific field as a science of interdisciplinary applicability.

Regarding the interdisciplinary approach in neurosciences, contemporary neuroscience, in the view of Lent (2010), "has a diversified approach, bringing different views, constituting another study alternative for students who are interested in the

⁴ The development and improvement of neuroimaging, electrophysiology, and molecular neurobiology techniques, as well as findings in the field of genetics and cognitive neuroscience, have enabled a great advance in knowledge in this area, despite the technical and ethical limitations regarding the understanding of cognitive processes as a whole (COSENZA and GUERRA, 2011, p.142).

intriguing phenomena of the brain" (p.02). In this light, the neuroscience of learning, broadly speaking, is the study of the ways in which the brain learns. Based on this point of view, it is possible to think of a dialogue between neuroscience and education, that is,

in a positive interference of neuroscientific knowledge in educational action, through the study of the structure, development, evolution and functioning of the nervous system, under a plural approach, that is, both biological, neurobiological and psychological, focused on the acquisition of information, problem solving and behavioral changes. Thus, the approximation between Neurosciences and Education can correspond to a better understanding of the learning process. Thus, offering learning situations based on experiences rich in stimuli and fostering intellectual activities can promote the activation of new synapses (DEMO, 2001, p. 50).

Given the above, based on Goulart (2015), a subdivision of neuroscience, such as the scientific study of the brain and the nervous system, is the so-called cognitive neuroscience, which addresses cognitive processes⁵, such as memory and attention, which involve thought and its complex relationships with language structures, learning and the influences of the outside world, mediating sociocultural development in the historical process of the individual.

In this line of understanding, it is worth noting that the knowledge resulting from studies in this area can collaborate to improve the understanding of how learning and the construction of increasingly elaborate mental processes take place. As a result, the combination of knowledge from neuroscience, education and psychology with the understanding of the structures and functioning of the brain to facilitate learning, referring to the concept of "neuroeducation" (MAIA, 2014).

This highlights the interdisciplinary character of neuroeducation, as a specific science, according to Tokuhamma-Espinosa (2011), as a field that acts at the intersection between neuroscientists' studies on cognition and the strategies applied to pedagogical processes. From this analytical basis, we can say, therefore, that neuroeducation emerged from the intersection of the areas of neuroscience, psychology and pedagogy, allowing a new look to seek to understand issues related to brain development, the functioning of

⁵Cognitive processes are those mental systems that govern the daily activities of the human being, such as reading, writing, talking, planning. Some systems support other systems, adding complexity in the generation of a behavior. The cognitive system of language, for example, involves the mechanism of speaking, reading, and writing, activating different brain structures. These different cognitive systems are based on different mental operations, which are related to neural networks of specific brain areas. The same authors cited add that learning progresses through dynamic flows of increasingly complex exchanges, analyses, and self-regulatory syntheses. In view of this, it is considered that the learning process goes beyond the simple accumulation of information, as it consists of restructuring, through structural changes arising from actions and interactions (POSNER and RAICHLE, 2001).



cognitive processes and human learning, corresponding, according to Lent (2019), "to studies that relate brain activity to learning and education in general" (p. 7).

Therefore, it should be noted that these theoretical contributions about neuroeducation are important for the study of human development, but they need to be analyzed with due caution, given that the dialogical weavings between neuroscience and education have not always been useful for interpreting the phenomena that are present in the school environment because, in the light of Amaral and Guerra (2022), "In many cases, scientific evidence is difficult to interpret and does not connect directly with the daily life of the classroom" (p. 15).

The idea of the existence of a discipline called neuroeducation can lead to a mistaken expectation, given that the brain does not explain everything about education. The discoveries of neuroscience do not solve all the problems of education. They should, however, be considered as explanatory bases on which other, more global levels are organized, involving interpersonal and social relationships (LENT, 2019, p. 9).

With this, we can consider that this multifaceted field crossed by different theoretical currents has studies focused on knowledge about the relationship between learning and the brain, focusing on cognitive skills and executive functions. Knowledge of executive functions, such as attention, memory, and perception, is also explored by neurosciences. To this extent, in line with Lent (2019), in early childhood, the stimuli of these functions in the prefrontal cortex enable a healthy development throughout the subject's life.

DISCUSSION

In the particular case of this study, it is important to consider that neuroscience offers knowledge related to learning and human development, as stated by Moraes and Torre (2004). This means that subjects learn when they express new knowledge or behaviors through a learning process (COSENZA and GUERRA, 2011, p. 141). Thus, it is imperative to agree with Assman (2001), when he asserts that learning is acquired and built throughout life, however, there are periods that are especially more receptive and others that depend on human experience.

Studies in the field of Cognitive Neuroscience emphasize that the individual, permanently in search of answers to his perceptions, thoughts and actions, has his neural connections in constant reorganization and his connective patterns altered at all times, through processes of strengthening or weakening of synapses. Thus, as in the brain, there are neurons ready for stimulation, mental activity stimulates the reconstruction of neural sets, processing experiences (IZQUIERDO, 2004).

It is worth emphasizing that cognitive neuroscience seeks to understand how cognitive processes are functionally elaborated by the human brain, enabling the

development of learning, language and behavior, as pointed out by Maturana and Varela (2001). Highlighting as themes of study, among others, the mechanisms of attention and memory, learning, emotion, language and communication. Thus, according to Ratey (2001), this field of study has contributed to the understanding of the learning processes and cognitive development of the human being. When considering cognitive neuroscience, whose focus of attention is the understanding of brain activities and cognition processes, it is clear that human learning results from the processing and elaboration of information from perceptions in the brain.

To this extent, considering the contributions of Relvas (2005), cognitive neuroscience has as its scope, in particular, the most complex mental capacities or higher mental functions, such as language and memory, the latter of which has been indicated as one of the main foundations of human learning. It is considered that higher mental functions are cognitively important for learning, because they favor an intrinsic relationship with language and allow the mediation of intellectual functions (IZQUIERDO, 2004). In this respect, information can lead the individual to develop cognitive strategies in order to reorganize and regain balance in the construction of knowledge.

In this way, a closer knowledge of the way the learning process works allows a more adequate understanding of its results. Complementing this idea, the author emphasizes that the scientific knowledge produced by neuroscience should be directed to those who, in some way, collaborate in the cognitive development of the subjects of learning (POZO, 2002). In this way, providing opportunities to understand how the brain is structured and works can provide more appropriate conditions to stimulate individuals cognitively and, in a way, enabling them to have their capacities better explored, considering that, in the view of Relvas (2014) "neuroscience is largely responsible for the discoveries of the functioning of the nervous system, in particular, of the brain" (p. 201).

In view of the above, the differences perceived in the form of development are more related to the mediation of the social context than to the biological aspects⁶. This principle arises from the conception that the development of higher psychic functions develops socially. In view of this, according to Cosenza and Guerra (2011), this development is possible through the relationships that each subject establishes with the environment in which he lives, and, therefore, it can be said that he is unique. From this perspective, attempts to generalize about development would not be justified, since this process is not

⁶ It should be noted that in addition to physical or biological laws, social aspects also influence education, which include, among others, the interactions between subjects, the dynamics of the teaching-learning process and the relationship of the educational institution with the family and the community (COSENZA and GUERRA, 2011, p. 143).



linear nor the same for everyone, since it depends on the experiences lived and the meanings applied to them, as emphasized by Relvas (2005).

In this line of understanding, concerning learning, cognitive neuroscience has a lot to teach, starting with the answers it provides to certain questions and questions, such as the meaning of what learning is for the brain, as well as the definition of the factors that influence and what can facilitate this learning, according to studies by Goulart (2015). From this perspective, learning for cognitive neuroscience is the modification of the brain with experience, that is, the brain changes in such a way that it starts to act in a different way according to previous experiences (HERCULANO-HOUZEL, 2017). In this aspect, it is an important task to explore and stimulate the potential to learn, aiming to provide better learning performance⁷.

This analytical basis allows us to understand that the evolution of knowledge produced about the brain constitutes one of the main alternatives to understand human cognitive complexity. And learning requires skills to deal in an organized way with new information, or with that already stored in the brain, in order to perform new actions. Thus, for Relvas (2014), learning is closely linked to the development of the brain, which is moldable to environmental stimuli. From this angle, not losing sight, as Cosenza and Guerra (2011) situate, that the brain is the most important part of the nervous system, because it is through it that we become aware of information, comparing it with our experiences and expectations.

Gaining relevance in this debate is the relationship between learning, linked to brain development, and memory, which, according to Lent (2019), "is the ability to encode, store and retrieve information, while only the storage process is identified as learning" (p. 13). Thus, according to recent neuroscientific research, learning and memory are different phases of the same progressive and continuous mechanism. In view of this, it is important to emphasize that memory, one of the most complex cognitive functions, is classified according to the time of retention of information, which varies according to different factors and its nature.

In this way, it is worth emphasizing that memory cannot be dissociated from learning, because through the conservation of previous experiences, a notion is established that confronts previous experience with present experience. Analyzing memory, from sensory stimuli to the final thought process (BEE, 2011). Thus, according to Lent (2019), "the concept of learning largely overlaps with that of memory, although both

⁷ Learning experiences through intentional practices, when well founded, generate changes in the structure of the individual (ASSMAN, 2001).

must be distinguished, considering memory as the global process and learning only as the stage of acquisition" (p. 13).

Considering that education aims at the development of new knowledge or behaviors, being mediated by a process that involves learning, it is worth pointing out here, according to the aforementioned author, that educating in this perspective of cognitive psychology and neuroscience, means providing care situations, in addition to representing the possibility of having moments for play and learning, oriented in an integrated way, contributing greatly to the development of people in their educability process, and it is important to provide educational spaces rich in stimuli from the first years of schooling. In this regard, it is in these first educational activities "that the seeds of social skills and personality are planted" (BEE, 2011, p. 456).

From this angle, it is up to the teacher to be concerned with the organization and application of activities that are valid for the students, it is also up to him to be prepared to provide students with contextualized learning, that is, considering their singularities and their own characteristics, since "whoever teaches, changes the brain of the other. Pedagogical strategies are stimuli that lead to the reorganization of brain connections, producing knowledge, skills, and attitudes" (AMARAL and GUERRA, 2022, p. 91). Because of this, the process of human formation encompasses all forms of education of the subjects, that is, it manifests itself in the family, community, society and culture where they live, as well as in their own school institutions, as pointed out by authors such as Moreira (2021) and Illeris (2013).

In fact, educational institutions are one of the contexts of motor, social, symbolic, emotional and cognitive development. From this point of view, the important thing is that the institution is conceived as another environment for socialization and not merely as a substitute institution for the family. Thus, for Illeris (2013), the school complements and integrates the family and the community by offering the student what he needs to develop in all aspects. In other words, "the person, in fact, is a cognitive-affective-motor whole, and the modification in one of the aspects affects the others. That is why it is often said that learning is global" (FALCÃO, 1986, p. 109).

In this horizon, learning⁸ is, first and foremost, a very complex issue, and there is no single generally accepted definition for the concept. On the contrary, there is a constant development of a large number of more or less singular or overlapping theories, some of

⁸ Learning occurs from the reorganization of synapses, circuits, and networks of neurons, interconnected and distributed throughout the brain, which involves and also promotes the development of mental functions, such as attention, emotion, motivation, memory, language, and logical-mathematical reasoning (AMARAL and GUERRA, 2022, p. 36).

them referring to more traditional views, others trying to explore new possibilities and ways of thinking. It is also worth noting that, although learning is traditionally understood as the acquisition of knowledge and skills, currently, the concept covers a much larger field, including other distinct dimensions. Thus, "learning is the process where the brain responds to environmental stimuli, activating synapses and making them more "accentuated", enabling the individual to resort to information and use it in the present" (FIRMINO and BRAZ, 2020, p. 1007).

Regarding this conception, it is quite difficult to obtain an overview of the current understanding on the subject of learning, according to Moreira (2021, p. 7). In this sphere, learning, despite being universal and occurring throughout life, is therefore not something simple to understand (ILLERIS, 2013, p. 49). In studies on the subject, different conclusions were reached about what is fundamental to understand the learning process. And this justifies, in part, the emergence of different theories to explain learning⁹. From this perspective, Maia (2014) emphasizes that "learning is a capacity that is developed throughout life, requiring the biological apparatus and neurocognitive readiness" (p. 12).

In this line of understanding, it is in the interaction/relationship with the environment that the subjects develop, building and reconstructing their knowledge and their hypotheses about themselves and about the world that surrounds them (PIAGET, 1976). It is interesting to consider that all knowledge is a construction resulting from the actions of the subjects who learn, in this way, access to school content is not reduced only to learning concepts and theories, but to making use of them, recognizing their function and also making social use of them. In this framework, intentional learning experiences stimulate reflections on thoughts, feelings and actions, in a constructive process, in the light of the theoretical perspective of authors, including Assman (2001) and Falcão (1986).

In general terms, it should be noted that the body is the starting point for the construction of knowledge and intellectual development, so that it is through movement, conceived as an essential aspect of integration with the world, that the nervous system will be elaborated and structured, favoring the organization of mental life, since working with the body allows subjects to perceive with all their potentialities and understand themselves emotionally. From this point of view, the role of education gains relevance for the integral formation of students, as there is greater development when well stimulated, in a well-

⁹ Generally speaking, a theory is a human attempt to systematize an area of knowledge, a particular way of seeing things, of explaining and predicting observations, of solving problems. A theory of learning is, then, a human construct to systematically interpret the area of knowledge we call learning. It represents the point of view of an author/researcher on how to interpret the theme of learning, which are independent, dependent and intervening variables. It tries to explain what learning is and why it works the way it works (MOREIRA, 2021, p. 12).



structured school, through games and self-knowledge, leading them to have greater interaction with their "corporeal self", knowing how to use it appropriately (FERREIRA, 2015).

By way of conclusion, learning involves complex processes and certain appropriate conditions and opportunities. Thus, in this important function from a biological point of view, the Nervous System (NS) is the fundamental figure for learning to occur. The teacher's role as a mediator aims to stimulate in students the desire to learn; continuously observing their reactions, giving guidance when necessary. Therefore, learning becomes effective when this mediation takes place in the school routine, as Maia (2014) reinforces.

FINAL CONSIDERATIONS

In view of all that has been exposed, which means taking into account the issues put into debate, it was clear that, despite the limitations imposed on the study, the research sought to highlight the interfaces between neurodevelopment and learning in the light of the theoretical perspective of neuroscience, a field of investigation that is undergoing significant advances. where the importance of enabling favorable conditions for the cognitive development of the subjects was perceived, with a view to realizing possibilities of meaningful learning, knowing that the creative and the recreative act are immanent to human activity (VYGOTSKY, 1998). In this regard, there are many strategies that involve cognition and this can contribute as a motivating factor for meaningful learning. Making the activity of teaching more pleasurable and the learning spaces more stimulating.

Knowing how we learn, knowing the mental functions involved in learning, the receptive periods, the relationships between cognition, emotion, motivation and performance, the potentialities and limitations of the nervous system, the difficulties for learning and the interventions related to them can contribute significantly to the understanding of a set of issues related to the school daily life (AMARAL and GUERRA, 2022, p. 36).

In general terms, it is ratified that this work analyzed that, in the school, the pedagogical work based on integral human development should provide the expansion of the experiences already built by the students, enabling knowledge and the construction of new ways of thinking, since in their experiences they formulate hypotheses, explore and reconstruct concepts. From this perspective, the assertion that knowledge of neuroscience discoveries can bring contributions to all actors involved in the teaching and learning processes is unassailable (ROSA, 2014). Therefore, it is imperative to agree with the authors mentioned in this study when they assert that the teacher and the student should relate autonomously, opening the chance in the largest possible dimension to form critical,



creative, up-to-date and competent men and women to face the challenges that the world proposes.



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