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PERSPECTIVES OF COGNITIVE NEUROSCIENCE AND ITS INTERRELATIONS WITH MATHEMATICS EDUCATION

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ABSTRACT

The purpose of this article is to present the main aspects highlighted in the work Educational Neuroscience: Initiatives and Emerging Issues organized by Katheryn E. Patten and Stephen R. Campbell, director of the Engrammetron laboratory (Educational Neuroscience and Mixed Research Laboratory). The choice of this theme is justified by the need to deepen the research, carried out by me, on mathematical concepts inherent to the constitution of the mathematical mind of individuals. In this study, carried out in 2017, I was able to show that this term is associated not only with the mathematical structure conceived by the community, but also with the mental biological structure (TALL, 2000). Therefore, it is possible to say that we are entering the multiprocessable, active and participatory system that corresponds to the human brain.

Keywords: Cognitive Neuroscience, Mathematics Education, Apprenticeship, Cognitive Processing.

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INTRODUCTION

The purpose of this article is to present the main aspects highlighted in the work *Educational Neuroscience: Initiatives and Emerging Issues* organized by Katheryn E. Patten and Stephen R. Campbell, director of the Engrammetron laboratory (*Educational Neuroscience and Mixed Research Laboratory*). The choice of this theme is justified by the need to deepen the research, carried out by me, on mathematical concepts inherent to the constitution of the *mathematical mind* of individuals. In this study, carried out in 2017, I was able to show that this term is associated not only with the mathematical structure conceived by the community, but also with the mental biological structure (TALL, 2000). Therefore, it is possible to say that we are entering the multiprocessable, active and participatory system that corresponds to the human brain.

Assuming that mathematical concepts are conceived from such associations, I searched in the works organized by *Katheryn E. Patten* and *Stephen R. Campbell* and other members of their research group, the possible contributions to this theme. Thus, I present a brief summary and the main ideas that guide the works of Fenna van Nes, Paul Howard-Jones, Anthony E. Kelly and Kerry Handscomb.

THE MAIN IDEAS PORTRAYED BY THE RESEARCH GROUP

In one of his works, Campbell[2] (2010) states that phenomena pertinent to Mathematics Education have been studied from perspectives aligned with Cognitive Neuroscience, promoting a new era of investigation that considers new opportunities for educational research. However, the author's work shows that the results are suggestive and illustrative, and cannot be considered definitive or comprehensive.

The aforementioned author refers to the term Neuroscientific Education or Educational Neuroscience[3] and argues that the "brain-based education" movement has been known[4] (Campbell, 2010, p. 310). He adds that there is a huge gap between the study of physiological structures and their mechanisms related to learning, raising a question that seems to be inevitable: why bother with this huge gap?

[2] Stephen R. Campbell earned a B.A. in Pure Mathematics and a Ph.D. in Education. He currently serves as an associate professor at the Faculty of Education and director of the Engrammetron (Educational Neuroscience and Mixed Research Laboratory) laboratory, belonging to Simon Fraser University in Canada.
[3] Translation of Educational Neurosicence
[4] Our translation: brain-based education.

According to Campbell (2010), the study of mental functions, brain structures and physiological behavior has advanced as a result of the dedication of cognitive psychologists, computer scientists and neuroscientists, psychophysiologists and geneticists. Such interdisciplinary efforts in cognitive neuroscience have been fueled by a growing knowledge base of studies of brain injury and its impairment of functioning, as well as technological advances in brain imaging that have revealed its physiological and behavioral structure.

Campbell (2010) admits that with the recent advances in brain imaging, there is a great interest of researchers in knowing what will be the role of Neuroscience in the educational area and vice versa. It goes on to state that initiatives seek to establish the relationship between both areas of research, involving parts of Cognitive Psychology and Cognitive Neuroscience. The author calls this union Neuroscientific Mathematics Education and identifies in it the potential to become an important, if not revolutionary, area of research in Mathematics Education.

According to the research of Nes[5] (2010), researchers in Mathematics Education are becoming more aware of the benefits of applying neuroscientific methods directed to Education. She identifies that neuroscientific research can enrich both educational research and that of its own area, in the recognition of cognitive processes that are recognized from the relationships of brain-circuits, thus allowing changes in brain activities as a consequence of the learning function to be perceived.

In her work, the author seeks to establish a relationship between mathematical educators and neuroscientists in the recognition of the learning mechanisms that are involved in the development of children's number and spatial sense, evidencing the role of the ability to standardize and spatial structuring and what is its effect on future mathematical performance. Thus, he argues that the objective of the mathematical educators in their project is to identify the constitution of spatial structures and their role in the development of more sophisticated numerical procedures.

Campbell (2010) refers to the relevance of Neuroscience to Psychology and Education and identifies that there are different levels of analysis that provide different answers to the same questions. He illustrates this argument from different responses that are devised by physicists, physiologists, and psychologists when watching a

[5] Fenna van Nes completed her doctorate at the Institute of Science and Mathematics Education in Utrecht (Netherlands).

baseball game. Based on the question: *Why does the pitcher throw a curveball?*[6], presented to the group, it becomes evident that researchers in education are reluctant to reduce psychological issues to physiological views, much less to views related to Biology, Chemistry or Physics. There are, however, interfaces between these different levels of analysis and, especially, between Psychology and Physiology in particular that must be interrelated in a coherent way. In this sense, Campbell (2010) considers that very little is known about the functioning of the brain from this point of view, and that *brain science* [7](p. 312) is in such flux.

It goes on to state that embodied changes involving emotions, such as anxiety, are quickly evidenced in organs of the body connected to the brain from the peripheral nervous system, such as the skin, heart and lungs. Thus, cognitive emotional responses correspond to alterations in the brain system associated with a variety of cognitive functions, such as perception, memory, creativity, reasoning, and others, making evident the embodied manifestations of human cognition.

He emphasizes that Cognitive Neuroscience should not be scientifically oriented in terms of neural structures, their biological mechanisms, computational processes and their functions. On the other hand, it should emphasize a humanistic orientation oriented to Educational Neuroscience, as a new area that will access methods of Cognitive Neuroscience, especially summoned for the purposes of the experiences lived by educational practices and problems.

In another work, Campbell and Patten (2011), from a scientific point of view, emphasize that greater observation of perspectives arising from the study of the brain, body and behavior may promote the creation of better opportunities to measure, identify and understand the new phenomenon and significant factors associated with the cognitive and social development of various aspects of teaching and learning, elevating and identifying our understanding of the human condition.

For the authors, the fundamental assumption of Educational Neuroscience is that all human cognition, that is, all subjective sensation, memory, thought, and emotion can, in principle, be observed from the behavior of the human organism. However, all physical behavior is only a part or part of the subjective flow of lived experiences that are observed, analyzed, and interpreted based on physiological changes that can be

[6] Our translation: Why did [the pitcher] throw a curve ball?
[7] Translation: brain science.

visualized by appropriate methods and techniques. Such brain images can reveal fluctuations in brain state that are related to affective aspects and cognitive functions.

Analogous to the ideas of Campbell (2010) and Campbell and Patten (2011), Handscomb (2010) states that one of the assumptions of Educational Neuroscience is that experience and cognitive functioning (such as, for example, mathematical reasoning) are incorporated into the neural activity of the brain. In other words, there is a relationship between subjective cognitive functioning and objective neural activity, in such a way that knowledge of one implies knowledge of the other.

Also according to Campbell and Patten (2011), in a positive way, the focal point of Educational Neuroscience is related to living human beings and not only to the physiological and biological mechanisms underlying them. There are, therefore, objective changes in the body that are manifested after the exercise of mental processes.

They assume that there is a correlation between subjective experience and embodied behavior and add that the term mind-brain should not be considered separately or in isolation.

In these same works, I identified references to the EEG, EKG and ET methods[8] used in the study of the behavior of the brain and the human body in learning processes, in an initiative that has been known as Educational Neuroscience.

Among the methods mentioned, EEG corresponds to a non-invasive technique that allows the researcher to identify the duration of brain signals from a given stimulus and the motor and perceptive reactions of the individual under different experimental conditions.

The above-mentioned comments regarding the embodied manifestations of lived experiences have offered a spirit of provocation of change. The authors add that educational research cannot renounce such humanistic orientations and point to some questions: What types of psychophysiological manifestations are detected, measured and recorded in the minds and bodies of students during the formation of a given mathematical concept? They also continue: What changes in brain activity can be observed or measured during the formation of a certain concept, hypothesis, or moments of *insight* that are evidenced by methods such as EEG? In the same way, is it

[8] EEG: electroencephalograph; EKG: electrocardiograph; ET: eye-tracking.

possible to observe and measure the responses obtained from the prospection of anxiety or affective activities or reactions, reflected in methods such as EKG or GRS[9]?

For Campbell (2010) it is important to identify the various signs related to cognition and affect that are incorporated and manifested during the teaching and learning of a given concept.

The authors argue that the use of methods from Psychobiology and Cognitive Neuroscience such as EEG, EKG, ET and GSR in educational research are new ways of operationalizing educational models based on Psychology and Sociology and that were traditionally developed to interpret the mental states of organisms and their social interactions.

Among the members of the Neuroscience Education group supervised by Professor Stephen R. Campbell, Kerry Handscomb researches how different geometric images are perceived by the cerebral cortex and cerebellum, suggesting that there are implications in the theories of Mathematics Education that involve aspects of abstraction and generalization. In his work, he hypothesizes that decontextualization in the learning of mathematical concepts can represent a significant factor in the development of students' ability to perceive and infer geometric objects.

For Handscomb (2010), the direct perception of the structure is an indispensable cognitive function for the geometric solution. His research is aligned with certain structural aspects of visual perception, referring to it as perception of structure or schematic perception. However, the author reports that aspects of logical reasoning perception are also inherent to such cognitive functions.

In his analysis, there is the identification that the concept of a line or a circle is linked to a specific pattern of neural activity. According to the author, there are two ways people interact with the world: through action and through perception. Sensation contributes to perception while action moves the world. There is a continuous cycle between perception and action: action leads the movement that alters sensation and perception alters. Consequently, we have a new action. According to the author, it is in this way that human interactions occur from this continuous movement.

Focusing on neurophysiological aspects, the author assumes the hypothesis that the cerebellum is related to the schematization of geometric concepts and to higher cognitive functions.

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[9] GSR: Galvanic Skin Response.

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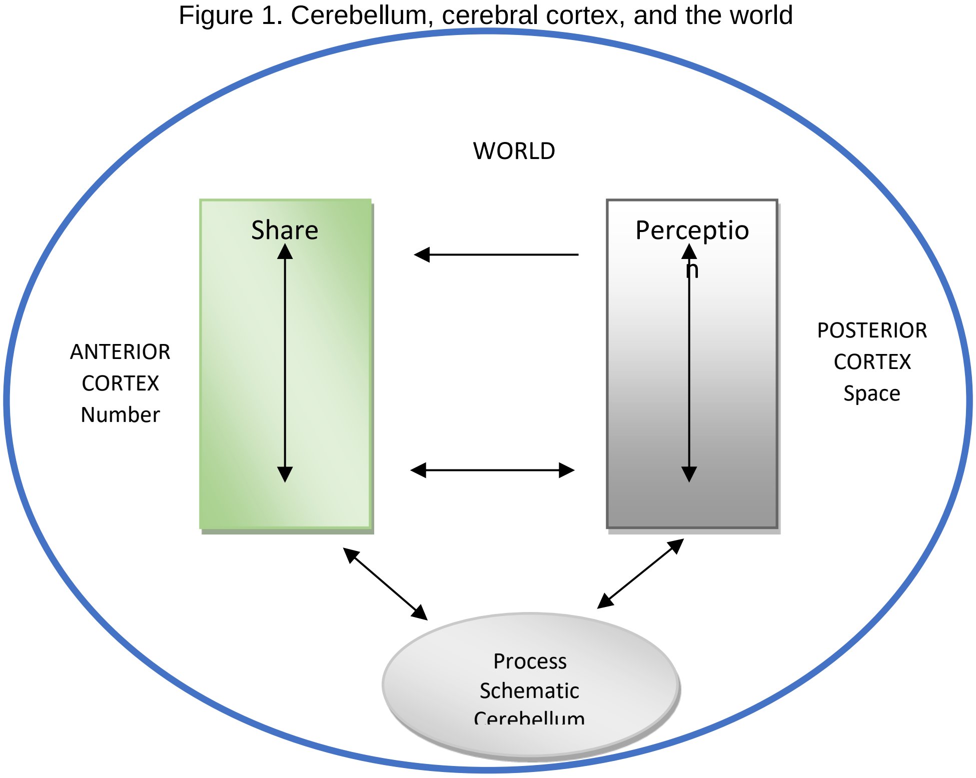
It continues with the statement that there are important consequences for Mathematics Education arising from theories of the cerebral cortex. In general, the anterior cerebral cortex is related to arithmetic and algebraic reasoning, basically guided by procedural reasoning. Conversely, the posterior cerebral cortex is associated with geometric reasoning, which is guided by perception. He adds that his interpretations of Cognitive Neuroscience take the perspective of a mathematical educator.

He adds that there is evidence that theories of Mathematics Education refer to aspects of Neurophysiology, evidencing the different types of reasoning conceived by the frontal and posterior cerebral cortex.

Particularly, the schematization of concepts and perceptions is related to the process of abstraction, which in turn has been the focus of intense discussion among mathematics educators.

Figure 1. Cerebellum, cerebral cortex, and the world



Fonte: Adapted from Handscomb, 2010

The author asks mathematical educators and cognitivist neuroscientists to place themselves between both areas when they read his research, because his work belongs first and foremost to Educational Neuroscience. This seeks to integrate and synthesize both areas of knowledge, until then, separate and divergent.

At this point, we present a summary of the work of another member of the research group led by Stephen R. Campbell, Anthony E. Kelly. At first, Kelly (2011) asks: can Cognitive Neuroscience become a science of learning?

Among his study perspectives, the aforementioned author seeks to highlight the study of the neural basis of mathematical thinking and its reading coding processes.

He recognizes that the "state of the art" in Cognitive Neuroscience research is still in the early stages and that it will take decades to mature.

Among the analyses of his work, he identifies that the understanding of concrete and abstract concepts, attention and memory are related to specific systems of the brain.

According to Kelly's (2011) research, fundamental aspects of learning begin with the understanding of terms of neural processes and their biological contexts. Such discoveries, in these and other areas, are influencing our understanding of the environment, cognition, and the nature of human learning.

Another research that I highlight in this article is that of the author Paul A. Howard-Jones.

For Howard-Jones (2011) it is possible to identify trajectories in which each multidisciplinary research is anchored in the biological basis of human learning that may alter educational practice.

He adds that neuroscience seen from an educational point of view can reveal experience and concepts from both perspectives (neuroscience and education), seeking to highlight the importance of human development in the social context and its interpretation of meaning. For the author, for now, neuroscience is more dedicated to controlling experiments based on hypothesis tests and the identification of cause and effect mechanisms that can be generally applied, making both perspectives still isolated.

It describes that in Cognitive Neuroscience, the term *learning* is related to the individual's level of general memorization skills. The author refers to declarative memory as our ability to explicitly recall facts, but also non-declarative aspects of memory such as the acquisition of skill and habits conditioned to emotional responses and also the habit to a repeated stimulus. Educators, on the other hand, describe learning in terms of social constructions, from authentic exploration, engagement of activities, and intuition to group work.

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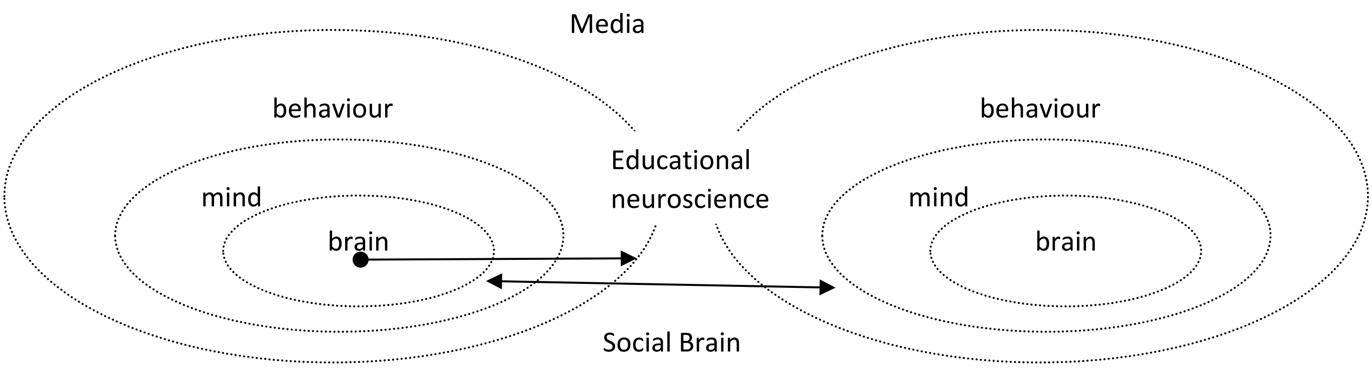
However, it shows that there is a growing number of seminars that highlight the growth of action levels of models that deal with the study of the complex interrelationship between the different learning philosophies that are found in this emerging field. For the author, there is evidence of how different methodologies associated with educational research and neuroscience are interrelated in neuroeducational research.

Howard-Jones (2011) cites the brain-mind-behavior model → → of Cognitive Neuroscience adopted by Morton and Frith (1995) and emphasizes social processes.

Figure 2 presents the interaction between two individuals in the construction of knowledge. It can be the teacher and the student or, perhaps, two students. The distance between them is separated by a sea of symbolic human representations in their most diverse forms.

Figure 2: A multi-perspective approach to neuroeducational research



Fonte: Adapted from Howard-Jones, 2011

This figure illustrates the lines that separate brain, mind, and behavior. The author points out that between these lines there is a sea of symbols that show the difficulty in separating the concepts involved.

In order to understand the issues presented to the students' universe and to identify their actions or strategies and also those of the teachers, the use of multiple, ambivalent and transitory languages is included. However, the production and perception of language have borne fruit in areas based on scientific laboratory research and the interpretation of meaning in everyday contexts.

For Howard-Jones (2011), neither social nor natural science, in isolation, currently offers sufficient epistemological "traction"[10] to travel through all the levels of description presented in Figure 2.

Cognitive Neuroscience highlights the extension of the brain to behavior and reflects the current difficulties in penetrating meaning based on social interactions. The author adds that the role of Cognitive Neuroscience has been essential to support a careful consideration of individual mind-brain relationships with biological and psychological evidence, improving the understanding of teaching and learning strategies at the different levels of action (Figure 2).

In the section of his work, entitled *Changes, Outcomes and Implications*, the author points out that those seeking to work at the interface of neuroscience and education will encompass quite different philosophies about learning, each expounding a very different set of concepts. To this end, it is up to researchers to face such changes in the use of language and the development of new concepts that clearly reside within the limits of sense as interpreted by both communities.

It points out that among the dangers evidenced in the extremes of mind-brain relations is that some issues can be considered entirely *medicalized*[11], being characterized only by biological aspects and thus removed from the domain of influence of educators.

In the field of Cognitive Neuroscience, researchers argue that mind and brain should be explained together. The notion of mind is considered theoretical, but it is an essential concept for exploring the emerging relationship between our brain and our behavior, including our learning.

CONSIDERATIONS

Based on the research of the group coordinated by Professor Stephen R. Campbell, I obtained the first steps that make up this investigation. The group sought to identify in theories and practical experiments the interrelationship that is established between aspects of Cognitive Neuroscience and Education, attributing to the name Neuroscientific Education the role of the neurophysiological mechanisms underlying cognitive functions. However, they consider that Mathematics should be at the center of

[10] Translation of epistemological traction.
[11] Translation of medicalised.

the problematization, considering life experiences, social contexts, that is, their humanistic orientations.

As Campbell and Patten (2011) have exposed, the focal point of Educational Neuroscience is in living human beings and not only in the physiological and biological mechanisms underlying them. For them, the causal effects manifested in the minds of the individual are responsible for the changes that occur in their organism, perpetuating a materialistic view.

However, we should not disregard that we are first and foremost Mathematical Educators, and we should focus on the interpretations of Cognitive Neuroscience with the focus of this educator. Therefore, it is important that we pay attention to both areas, in a single way and never separately.

By understanding the interrelationship that is established between the areas, it is possible for us to identify the mind-brain behavior that allows us to develop new teaching and learning strategies inherent to each individual, in a particularized way.

Therefore, I understand the student as an individual full of experiences and meanings, anchored in a unique biological base, but not isolated.

I emphasize that the issues pointed out by the authors who revealed their concerns and mine about this theme are not definitive and are still in an initial moment of investigation, but growing.

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REFERENCES

1. Campbell, S. R. (2010). Embodied minds and dancing brains: New opportunities for research in mathematics education. In B. Sriraman & L. English (Eds.), Theories of mathematics education – Seeking new frontiers (pp. [pages]). Berlin Heidelberg: Springer.

2. Campbell, S. R., & Patten, K. (2011). Introduction: Educational neuroscience. In Educational neuroscience: Initiatives and emerging issues (pp. [pages]). United Kingdom: Wiley-Blackwell.

3. Handcomb, K. (2010). On the psychological and physiological foundations of structure in geometry: A study in educational neuroscience (Doctoral dissertation). Faculty of Education, Simon Fraser University, Burnaby, Canada.

4. Kelly, A. E. (2011). Can cognitive neuroscience ground a science of learning? In Educational neuroscience: Initiatives and emerging issues (pp. [pages]). United Kingdom: Wiley-Blackwell.

5. Howard-Jones, P. A. (2011). A multiperspective approach to neuroeducational research. In Educational neuroscience: Initiatives and emerging issues (pp. [pages]). United Kingdom: Wiley-Blackwell.

6. Nes, F. v. (2010). Mathematics education and neurosciences: Towards interdisciplinary insights into the development of young children's mathematical abilities. In B. Sriraman & L. English (Eds.), Theories of mathematics education – Seeking new frontiers (pp. [pages]). Berlin: Springer.

7. Tall, D. (2000). Biological brain, mathematical mind & computational computers: How the computer can support mathematical thinking and learning. University of Warwick, UK.