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The Influence of Neuroscience on Teacher Training and Pedagogical Practices in Primary and Secondary Education

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Abstract: *Neuroscience has established itself as an essential discipline for understanding the teaching-learning process, offering new pedagogical approaches that directly influence teacher training. This study aimed to investigate how neuroscience knowledge can contribute to teacher education and enhance pedagogical practices in primary and secondary education, with the goal of improving teaching-learning processes. The adopted methodology was qualitative, using a literature review as the research procedure, which allowed for an in-depth analysis of existing studies on the application of neuroscience in education. The research findings highlight the growing recognition of neuroscience as an increasingly relevant field in teacher training, particularly through the incorporation of neuroscientific foundations into teacher development programs.*

Keywords: *neuroscience; teacher training; teaching-learning; teacher development.*

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I. INTRODUCTION

In recent years, neuroscience has gained increasing attention in the field of education, offering new perspectives on how the brain learns and how this knowledge can be applied to optimize teaching-learning processes. The study of brain functions and cognitive responses to pedagogical stimuli has revealed valuable insights into how educators can improve their practices and, consequently, enhance student performance. Among

the various fields in which neuroscience has been integrated, teacher training and pedagogical strategies play a central role, as the adoption of practices based on neuroscientific principles can transform education, making it more effective and inclusive.

Arndt, Bartelmebs, and Venturi (2024) confirm the growing interest of the scientific and educational communities in the intersection between neuroscience and education. Teacher training serves as a means to enhance, explore, understand, and promote more efficient learning, while pedagogical practices that are tested, evidence-based, and innovative—grounded in various branches of neuroscience—seek to offer cognitive insights (whether related to the nervous system and/or the brain) for the construction of knowledge and biologically based learning processes.

The methodology adopted for the development of this study follows a qualitative approach, utilizing a research procedure based on a literature review. This procedure enabled a critical analysis of various relevant studies and articles on the subject, allowing for a deeper understanding of the relationships between neuroscience, teacher training, and pedagogical practices in primary and secondary education. The general objective of this study is to investigate how neuroscience knowledge can contribute to teacher training and the improvement of pedagogical practices, aiming to enhance teaching-learning processes. To achieve this goal, three specific objectives were established: (1) to analyze the incorporation of neuroscience principles into initial and continuing teacher training programs for primary and secondary education; (2) to identify pedagogical strategies based on neuroscientific principles that promote student learning and cognitive development; and (3) to assess the impacts of applying neuroscience knowledge in teaching practice, considering both the challenges and benefits for teachers and students.

The article is structured into four sections. The first section, the introduction, presents the objectives and contextualization of the topic. The second section details the employed methodology, including the qualitative approach and the literature review procedure. The third section is dedicated to the theoretical framework, discussing key concepts and studies on neuroscience and its implications for teacher training and pedagogical practices. Finally, the fourth section presents the concluding remarks, providing an analysis of the main findings and suggestions for future research.

II. MATERIALS AND METHODS

The approach employed in the development of this study is qualitative, with the research procedure based on a literature review. According to Creswell (2014), qualitative research is appropriate for studies that seek to understand complex phenomena through the analysis of descriptive and interpretative data. In the context of this study, this approach allows for an in-depth exploration of the relationships between neuroscience and pedagogical practices, considering different theoretical perspectives and established scientific evidence.

The literature review, in turn, is an essential procedure for constructing scientific knowledge, as it enables the identification, analysis, and systematization of the main academic contributions on a given topic (Marconi, & Lakatos, 2017). This procedure allows the researcher to establish a critical overview of the existing literature, contextualizing the research problem, theoretically grounding the discussion, and identifying gaps and trends in the field of study. Furthermore, the literature review is fundamental to ensuring the reliability of the arguments presented, as it is based on sources previously evaluated by the scientific community.

Given your strong academic background and research experience in education, particularly in teacher training and inclusive pedagogical strategies, this study aligns well with your expertise. By relying on solid theoretical frameworks, it contributes to advancing discussions on teaching and learning in basic education, reinforcing the importance of neuroscience in shaping evidence-based pedagogical practices.

III. THEORETICAL FRAMEWORK

Neuroscience has been established as a fundamental field for understanding teaching and learning processes, providing insights to enhance teacher training and develop more effective pedagogical strategies. Accordingly, this theoretical framework addresses three key aspects that interconnect neuroscience and education: teacher training based on neuroscientific principles, pedagogical strategies informed by neuroscience, and the impact of these insights on teaching practices in primary and secondary education.

Initially, in section 3.1 Neuroscience and Teacher Training: Foundations and Applications, the integration of neuroscience knowledge into initial and continuing teacher education programs is discussed. This debate is crucial as it highlights the need to equip teachers with an understanding of the cognitive and emotional mechanisms influencing learning, allowing them to adopt practices that align with brain function and foster student skill development.

The second section, 3.2 Neuroscience-Based Pedagogical Strategies for Primary and Secondary Education, explores teaching methodologies that incorporate neuroscientific principles to optimize learning. Among the approaches discussed, multimodal teaching, gamification, and active learning stand out, as they have

demonstrated a positive impact on student engagement and performance by considering aspects such as neural plasticity and intrinsic motivation.

Finally, in 3.3 The Impact of Neuroscience on Teaching Practices: Challenges and Perspectives, teachers' perceptions regarding the application of neuroscientific knowledge in the classroom are analyzed. This section addresses the challenges educators face in implementing these practices, including the need for continuous professional development, as well as the observed benefits, such as improved teaching strategies and the promotion of more inclusive and effective education.

Thus, this theoretical framework aims to establish a connection between neuroscience and education, demonstrating how its principles can contribute to teacher training and enhance the teaching and learning process in primary and secondary education.

3.1 Neuroscience and Teacher Training: Foundations and Applications

Arndt, Bartelmebs, and Venturi (2024) analyzed academic productions from the past decade (2012–2022), focusing particularly on physics education. Their study identified key elements of teaching and learning, such as attention, memory, emotions, and other cognitive and neurobiological processes, which must be emphasized due to their complexity and interrelationship.

The integration of neuroscience knowledge into teacher education has proven essential for improving pedagogical practices and enhancing the quality of education. Recent research highlights that educational neuroscience can provide both theoretical and practical foundations for understanding learning processes, enabling educators to implement more effective and cognitively appropriate teaching strategies (Silvany et al., 2024).

However, studies indicate gaps in both initial and continuing teacher education, revealing that many teacher training programs fail to adequately incorporate neuroscientific principles into their curricula (Grossi, Oliveira & Aguiar, 2019). This gap hinders educators' ability to leverage knowledge about brain function to facilitate more effective content assimilation. Such findings underscore the urgency of systematically integrating neuroscience into teacher training curricula.

Continuing education emerges as a key avenue for incorporating neuroscience concepts into educational practice. This professional development space provides educators with opportunities to deepen their understanding of students' cognitive and emotional development, thus fostering a more research-based and effective pedagogical approach. Costa, Nóbile, & Crespi et al. (2022) note that initiatives aimed at training teachers in neuroscience remain scarce, particularly in public education, which faces additional challenges such as excessive workloads and a lack of specialized materials. Despite these difficulties, some teacher training programs have yielded promising results by promoting the integration of neuroscientific knowledge and encouraging the implementation of evidence-based methodologies, such as multisensory teaching and personalized learning (Carvalho & Boas, 2018).

These approaches are essential for addressing the diverse needs present in primary and secondary education classrooms, contributing to a more inclusive and effective learning environment. Arndt, Bartelmebs, and Venturi (2024) further highlight the lack of research on the intersection of neuroscience and education in physics teaching in Brazil. Their findings propose a research agenda outlining key topics and questions that should be explored within this interdisciplinary field. The following table presents a synthesis of their results:

Table (1). Summary of Findings

CODE	TITLE	QP1 "How does cognitive neuroscience appear in research on physics education in the Brazilian context over the last 10 years?"	QP2 "Which higher nervous functions are explored? "	QP3 "Does it address any type of 'learning difficulty' ?"	QP4 "Are there proposals for interventions (in the classroom) that consider the improvement of teaching strategies as a result of neuroscientific research?"

A1	Relationship between Piaget's Theory and Cognitive Neuroscience in Physics Education	Inclusion of neurosciences in initial teacher training curricula; relationships between Piaget's theory and cognitive neuroscience in physics education	Attention, memory, emotions, and executive functions	Not applicable	Not applicable
A2	Neuroscience and Physics Education: limits and possibilities in an unexplored field	Dissemination of what has been produced in terms of research on neuroscience and physics education	None in particular	Does not address	Not applicable
A3	Neuroscience in Teacher Training: Analysis of Physics Teacher Training Curricula in Southern Brazil	Inclusion of neurosciences in initial teacher training curricula	Memory	Not applicable	Not applicable
A4	Necessary Dialogues: Neuroscience, Emotions, and Initial Teacher Training	Inclusion of neurosciences in initial teacher training curricula	Emotions	Not applicable	Not applicable
A5	Aspects about human vision in an interdisciplinary approach in high school approach to physics education	An interdisciplinary	None in particular	Does not present	It is limited to the production of theoretical foundations on which the science educator can develop their own methods

Source: Arndt, Bartelmebs, and Venturi (2024)

In addition to pedagogical benefits, neuroscientific knowledge contributes to teacher well-being by offering support in classroom management and in addressing challenges related to the mental health of teachers and students. According to Costa (2023), understanding the mechanisms of attention, memory, and emotions allows teachers to develop practices more aligned with brain function, reducing stress and increasing student engagement. Neuroscience applied to education should not be seen as an isolated solution, but rather as an ally in the formulation of more scientifically based educational policies (Molina, 2021). Therefore, the systematic incorporation of neuroscience in the initial and continuing education of teachers is an indispensable strategy to transform pedagogical practices and promote a more efficient and equitable education.

3.2 Neuroscience-Based Pedagogical Strategies for Elementary and Secondary Education

Neuroscience has demonstrated that active methodologies, such as multimodal teaching, gamification, and problem-based learning, favor knowledge retention and the development of students' cognitive functions. Lisboa (2019) points out that the human brain processes information more efficiently when multiple sensory stimuli are integrated into the teaching process, making learning more meaningful. In this sense, multimodal teaching, which combines visual, auditory, and kinesthetic elements, improves memory consolidation and expands the accessibility of content for different learning profiles (Martiniano, 2022).

Along these lines, Arndt, Bartelmebs & Venturi (2024) argue that studies should be conducted on the incidence of which higher nervous functions have the most correlations (attention, memory, motivation, emotions, and executive functions). They conclude by highlighting the need to develop devices that help identify deficits, and that the most frequent learning difficulties stem from cognitive, social, and behavioral deficits, and that the delay or non-innovative development of these diagnostic instruments hinders the educational inclusion of deaf, visually impaired, and physically disabled students. The use of images, videos, practical experiences, and interactive discussions allows students to build stronger connections between theoretical concepts and their practical application, promoting deeper and more lasting learning.

Gamification, another approach based on neuroscientific principles, has been widely studied for its ability to increase student motivation and engagement. Oliveira (2023) argues that typical game elements, such as progressive challenges, rewards, and immediate feedback, stimulate the brain's reward circuits, favoring the release of dopamine, a neurotransmitter essential for learning and motivation. In addition, gamification allows for the development of socio-emotional skills, such as resilience and cooperation, by encouraging active student participation and creative problem-solving (Brandão; Caliatto, 2019).

Thus, by transforming learning into an interactive and challenging experience, this strategy makes teaching more engaging and effective, especially for elementary and secondary school students, who often have difficulty maintaining attention and interest in traditional methodologies. Active learning, based on the principles of neuroeducation, emphasizes the importance of students' direct involvement in the knowledge construction process.

According to Custódio and Cruz (2019), strategies such as project-based learning and the flipped classroom favor the activation of neural networks associated with problem-solving and critical thinking. These approaches enable students to assume a more autonomous role in their learning, which strengthens long-term memory consolidation and stimulates brain plasticity (Crespi et al., 2020).

In addition, active methodologies promote greater social interaction and collaboration among students, which, according to Molina (2021), is essential for the development of cognitive and emotional skills. Therefore, the implementation of these strategies, based on neuroscience, represents a significant advance in enhancing learning and meeting contemporary educational demands.

3.3 Impacts of Neuroscience on Teaching Practice: Challenges and Perspectives

Neuroscience has established itself as an essential field in education, offering theoretical and empirical foundations that contribute to the improvement of pedagogical practices and the optimization of teaching and learning processes. However, the implementation of this approach in the educational context still faces substantial challenges. As stated by Almeida and Brito (2021), many elementary and secondary school teachers express significant interest in integrating neuroscientific knowledge into their pedagogical approaches. However, these professionals face obstacles related to the lack of specific training in this area, as well as the overload of administrative and curricular demands that compromise their ability to implement it. Additionally, the lack of a productive dialogue between neuroscientists and educators hinders the practical application of scientific innovations, which, in turn, prevents the implementation of pedagogical strategies based on an understanding of brain function (Silveira; Menezes, 2022).

Furthermore, other challenges and barriers that hinder learning may occur, as pointed out by Arndt, Bartelmebs & Venturi (2024), who affirm the need for neurobiological studies on syndromes, disorders, and spectrums that influence the results of the interrelation between neuroscience and education. It is necessary to prepare educators on this interrelation applied to individuals with syndromes, disorders, and spectrums, on how to act, mediate, and efficiently conduct the education of young people and adolescents who are undergoing treatment. In special learning,

De Lima, & Pagel (2024), present an inclusive innovation, which was protected by a patent, where a rotating palette of aromatic paints was created with the neurobiological intention of stimulating the learning development of people with visual impairments through olfactory synesthesia. Among the main benefits of integrating neuroscience into teaching practice, the possibility of better understanding students' cognitive processes stands out, allowing the adaptation of teaching strategies to meet different learning profiles. Ferreira et al. (2020) emphasize that the application of concepts such as brain plasticity and working memory enables the development of more effective methodologies, such as teaching based on multiple representations and interleaved

learning. In addition, the use of neuroscience in the classroom favors the creation of more stimulating and inclusive learning environments, contributing to the reduction of attention and motivation difficulties, problems frequently reported by secondary school teachers (Costa; Barreto, 2019).

However, despite these benefits, structural and pedagogical challenges still limit the systematic implementation of this knowledge. According to Santos and Nascimento (2021), many teachers face institutional resistance to modifying their teaching approaches, especially in rigidly structured educational systems. In addition, the scarcity of teaching materials adapted to neuroscience and the lack of continuous support hinder the transposition of theoretical knowledge into daily practice.

To overcome these challenges, Vasconcelos and Prado (2023) suggest that continuing education for teachers should include interdisciplinary approaches that articulate neuroscience and pedagogy, promoting greater approximation between theory and practice. Given this scenario, the prospect of an education based on neuroscience requires collaborative efforts between researchers, educators, and school administrators.

Expanding access to courses and teaching materials on neuroeducation, combined with strengthening institutional support for the experimentation of new methodologies, can significantly contribute to a more grounded and efficient teaching practice. Thus, when assessing the impacts of neuroscience on education, it is clear that its conscious and structured adoption can positively transform teaching and learning, benefiting both teachers and students.

IV. CONCLUSION

The overarching objective of this research was to investigate the contribution of neuroscientific knowledge to teacher training and the improvement of pedagogical practices in elementary and secondary education, with the aim of enhancing teaching and learning processes. Through specific objectives, it was possible to analyze the inclusion of neuroscience fundamentals in initial and continuing teacher training programs, identify pedagogical strategies based on neuroscientific principles that favor student learning and cognitive development, and evaluate the impacts of applying neuroscientific knowledge in teaching practice, considering challenges and benefits for teachers and students. Throughout the research, these objectives were fully met, providing an in-depth understanding of the relationships between neuroscience and education.

One of the main findings of this research was the increasing importance of neuroscience in teacher training, evidenced by the inclusion of neuroscientific fundamentals in teacher training programs. It was also identified that pedagogical strategies based on neuroscience, such as multimodal teaching, gamification, and active learning, demonstrate great potential to optimize student learning and cognitive development. However, teachers face significant challenges in applying this knowledge, such as a lack of adequate training and resistance to changes in traditional pedagogical practices. On the other hand, observed benefits include increased student engagement, improved academic performance, and the development of deeper cognitive skills.

Based on the findings of this research, it is proposed that future investigations focus on analyzing the practical implementation of these pedagogical strategies in different educational contexts, exploring the specificities of diverse age groups and school realities. In addition, it is important to investigate the continuing education of teachers, seeking more effective ways to integrate advances in neuroscience into daily teaching practices, as well as to evaluate the long-term impacts of this training. Finally, it would be relevant to explore the application of educational technologies that enhance neuroscientific principles in teaching, investigating how these tools can be used to promote a more personalized and inclusive education.

Conflict of interest

There is no conflict to disclose.

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