NEUROEDUCATION IN ADHD: TRANSLATING NEUROSCIENCE INTO EFFECTIVE PEDAGOGICAL TOOLS

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Abstract

Classrooms are increasingly enrolling students diagnosed with attention deficit hyperactivity disorder (ADHD). Research suggests that, beyond medication, introducing various neurotechnologies in educational settings may help alleviate symptoms and support cognitive development in these children. This umbrella review compiles existing scientific evidence on the use and implementation of such techniques in schools. A systematic review was conducted in line with PRISMA guidelines, considering systematic reviews published in English or Spanish in peer-reviewed journals that focused on ADHD, applied neurotechnologies such as neurofeedback, transcranial direct current stimulation (tDCS), or hyperscanning, and addressed educational contexts. Fourteen reviews met the criteria, highlighting neurofeedback as the most frequently studied method, though its practical application in schools has been limited and primarily examined for efficacy. tDCS emerged with a stronger clinical orientation, while no evidence of hyperscanning in schools was found. Although experimental findings are encouraging, further ecological studies are required in order to explore the practical implementation in educational environments. Moreover, advancing neuroeducation may require the development of new professional roles.

Keywords: *neuroeducation, ADHD, executive function, brain-based learning, pedagogy.*

1. INTRODUCTION

This article explores the emerging field of neuroeducation and its relevance for teaching students with ADHD. Neuroeducation bridges the gap between neuroscience research and classroom practice, offering evidence-based strategies that align with the learning processes of the brain. The article reviews key neuroscience findings on attention, executive function and memory, and translates them into practical tools for educators. These include spaced repetition, multisensory instruction, brain breaks, and metacognitive strategies. The importance of teacher knowledge regarding brain development and plasticity is emphasized, as it enhances empathy and effectiveness in managing learning and behavioural challenges. The article also reviews common misconceptions about "brain-based" learning and stresses the need for the critical application of scientific evidence in education. By grounding pedagogy in neuroscience, the paper argues that teachers can create more inclusive and effective learning environments for students with ADHD and related conditions.

Neuroeducation, an interdisciplinary field connecting neuroscience, psychology, and education, provides valuable improvement perspectives for teaching and learning practices. As scientific knowledge of how the brain influences learning expands, educators are seeking strategies to apply these insights effectively in classrooms. This article reviews the theoretical foundations of neuroeducation, discusses its applications in modern educational contexts, and addresses the challenges associated with its implementation. This study investigates educators' perceptions, preparedness, and potential obstacles to adopting neuroeducation principles in their teaching. The results highlight the significance of understanding brain functioning, emotional regulation, cognitive growth, and motivation in order to foster inclusive, engaging, and effective learning environments. Neuroeducation not only enhances personalized learning but also strengthens teacher-student connections and supports diverse learners, including those with neurodevelopmental differences. The study stresses the necessity of collaboration among neuroscientists, psychologists, and educators, while also emphasizing the importance of designing teacher training programs that integrate neuroeducation effectively. Furthermore, it underscores the need for future empirical research to validate and extend practical applications, ensuring that advancements in neuroscience contribute meaningfully to classroom practices and educational policy.

Table 1. Summary of Neurotechnological Interventions in ADHD and Education

Neurotechnology	Mechanism	Key Findings	Application in Education	Limitations
Neurofeedback	EEG-based brain-computer interface for self-regulation	Improves academic performance and some ADHD symptoms (Meisel et al., 2014)	Classroom use promising but limited	Mixed results; more ecological studies needed
tDCS	Electrical stimulation to enhance neural activity	Reduces ADHD symptoms, improves inhibitory control and learning (Salehinejad et al., 2020; Nejati et al., 2022)	Potential classroom tool for focus & executive function	Mostly clinical, not yet widely used in schools
fNIRS Hyperscanning	Simultaneous measurement of neural synchrony	Neural synchrony linked to better learning (Zhang et al., 2022)	Useful for studying teacher-student interactions	Limited classroom studies; still experimental

1.1 Neuroscience and Teaching

The integration of neuroscience into education—commonly referred to as neuroeducation—has gained notable attention in recent years. By understanding how the brain processes learning, educators can design more effective teaching strategies and respond more appropriately to the diverse needs of students (Valdés-Villalobos & Lazzaro-Salazar, 2023).

As an emerging interdisciplinary field, neuroeducation aims to improve the efficiency of teaching by connecting findings from neuroscience with classroom practices. While it does not replace pedagogy, neuroscience enriches instructional methods with physiological insights, offering teachers guidance in selecting models and approaches that can enhance learning effectiveness (Dubinsky et al., 2022).

Although debates continue regarding the extent of neuroscience's contribution to education, scholars generally agree that psychology plays a key role in advancing student learning across all ages and levels (Bowers, 2016). With input from neuroscience, educational psychology, cognitive psychology, and pedagogy now collectively inform the growing field of neuroeducation (Bhargava & Ramadas, 2022).

At its core, neuroeducation integrates scientific knowledge regarding the brain function and psychological processes with the teaching practices. It seeks to address two essential questions: Can learning strengthen the mind? and Can insights into brain functioning help teachers refine their instructional practices?.

Neuroeducation is therefore recognized both as an academic field of study and as a professional practice. Its development, supported by evidence on learning outcomes, contributes to the establishment of a new specialization within teachers' professional development. The aim is to enhance learning experiences at individual, group, and institutional levels.

This interdisciplinary approach bridges gaps between educators, psychologists, and neuroscientists. It allows for more informed teaching practices grounded in how the brain and mind operate, which has both strengths and limitations. On the positive side, neuroscientific insights can improve interventions for children with developmental or behavioural challenges (Sina et al., 2024). However, misinterpretations of neuroscience findings risk perpetuating "neuromyths," misconceptions that may hinder learning. For this reason, neuroeducation also promotes critical reflection and ethical awareness to prevent the misuse of scientific knowledge.

Despite the complexities and challenges, teachers—regardless of time constraints or institutional pressures—recognize that neuroscience can play a meaningful role in enriching both teaching practices and student learning (Bartoszeck & Bartoszeck, 2012).

1.2 The Brain and Learning

Neuroscience and anthropological research on brain evolution show that human brain development is shaped more by lived experiences than by biological predispositions. In this sense, the brain functions primarily as an organ designed for learning, highlighting the responsibility of teachers, parents, and education systems to seek effective approaches for children's education (Darling-Hammond et al., 2023).

Advances in neuroscience have deepened our understanding of what occurs in the brain during learning, demonstrating that brain plasticity allows structural and functional changes as new knowledge is acquired (Tartari & Lutaj, 2021). Although traditionally disconnected from pedagogy, these discoveries have encouraged educators to explore the practical application of neuroscience in the classroom, giving rise to the emerging field of neuroeducation (Chang et al., 2021).

However, teachers face challenges in translating theoretical findings into practice. They require concrete strategies and programs rather than abstract discussions about brain mechanisms. Classroom realities often prioritize immediate learning outcomes, leaving little room to integrate neuroscientific insights into daily practice (Hardiman et al., 2012).

From a biological perspective, learning is strongly influenced by the environment, which activates and regenerates cognitive abilities. Likewise, creating emotionally supportive classrooms enhances motivation and learning, requiring teachers to manage both students' and their own emotions. In this way, neuroeducation supports not only cognitive growth but also physical and emotional development .

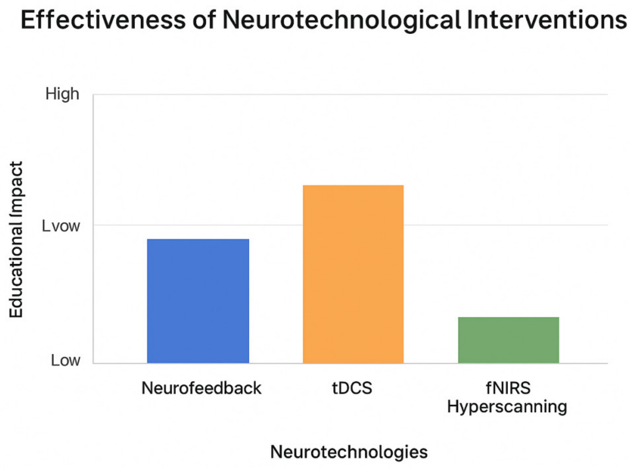

Fig. 1. The comparing of effectiveness across three interventions based on educational impact

1.3 Application in Teaching

In the 21st century, schools are increasingly adopting competency-based learning models, which prioritize the acquisition of skills and knowledge over time spent in class (Qafa et al., 2024). This approach allows for individualized, self-directed learning and greater student autonomy. Traditional teaching methods, however, often struggle to align with these new demands, requiring teachers to shift toward more flexible, multidimensional approaches that encourage discovery and exploration.

Neuroeducation provides a scientific foundation for understanding how students learn, taking into account the neurocognitive and metacognitive development. It also sheds light on the effects of neurodevelopmental disorders such as ADHD or autism, which significantly influence learning processes. Although teachers are increasingly adopting strategies informed by neuroeducation, their knowledge in this area remains limited (Extremera et al., 2021).

This gap stems largely from the insufficient collaboration between neuroscientists, psychologists, and educators. Direct partnerships are essential, as teachers' needs and classroom realities cannot be fully addressed through mediated research alone (Hachem et al., 2022). Moreover, teacher training programs often lack structured instruction on the practical application of neuroeducation. Jolles & Jolles (2021) identify three main barriers: (1) research results are often clinical rather than pedagogical; (2) accessible resources for teachers are scarce; and (3) communication between neuroscience and education lacks a clear common language.

Another challenge lies in the spread of *neuromyths*, or misconceptions about the brain function, which are often amplified by commercial platforms and can unintentionally distort teaching practices (Seccia & Allee, 2024). To avoid this, effective communication, ethical reflection, and scientifically grounded training are crucial.

Despite these barriers, the interdisciplinary nature of neuroeducation—drawing from neuroscience, psychology, cognitive science, and pedagogy—offers opportunities to reshape teaching practices. Teachers who recognize its value are more likely to adopt innovative approaches and persist in applying them. Yet, as Pickering & Howard-Jones (2007) note, many educators still lack clarity and depth in understanding how neuroscience can inform teaching. Intensive dialogue between researchers and teachers is therefore essential (Serpati & Loughan, 2012).

Empirical studies suggest that neuroeducation can be successfully implemented in classrooms (Robb, 2016). Nevertheless, broader adoption requires systemic change. Universities, teacher-training institutes, and professional development programs should design interdisciplinary curricula and resources to embed neuroeducation into teacher preparation. Furthermore, building a competency framework would help define the skills teachers need so that they can effectively apply neuroeducation into practice.

2. METHODOLOGY

This study evaluates teachers' knowledge of neuroeducation, their perceptions of its classroom relevance, and the extent to which it influences their teaching practices. The research poses two central questions:

Can education improve brain functioning?

Can understanding the brain enhance teaching and learning in schools?

A literature review was also conducted, focusing on the relationship between brain development and children's learning. Sources were categorized according to three guiding questions:

What do teachers know about brain development and its impact on learning?

How confident are teachers in applying neuroeducation in classrooms?

To what extent do teachers implement neuroeducation principles in practice?

3. RESULTS

3.1 Neurofeedback

Neurofeedback was the earliest neurotechnology applied to ADHD, first explored in the 1970s (Arns et al., 2014), and it has since encouraged the study of other related techniques. Based on electroencephalographic (EEG) recordings across different brainwave frequencies, neurofeedback is defined as "a self-regulation technique that uses a brain-computer interface (BCI) to influence neural plasticity and efficiency by providing the individual with information about their brain's electrical activity" (Cannon, 2015). Through operant conditioning and training, individuals learn to adjust their brain activity when the interface signals inappropriate patterns. Although criteria for determining "appropriate" activity vary, neurofeedback has been widely researched as a potential treatment for ADHD and continues to attract significant interest.

Empirical evidence suggests encouraging results. For example, Meisel et al. (2014)

conducted the first randomized trial with a six-month follow-up comparing neurofeedback with pharmacological treatment, finding similar reductions in functional symptoms but greater improvements in academic performance among the neurofeedback group. Kuznetsova et al. (2022) also observed that while neurofeedback is effective for learning outcomes, its impact on alleviating ADHD-specific symptoms appears less robust.

3.2 Transcranial Electrical Stimulation (tDCS)

Transcranial electrical stimulation, which uses electromagnetic current to stimulate neural activity, has been studied as a complementary or alternative intervention to medication for enhancing cognitive functions and learning in individuals with neurological disorders (Camacho-Conde et al., 2022). Different modalities exist, with varying degrees of invasiveness, and many studies focus on optimizing technical parameters to maximize effectiveness. Evidence suggests that tDCS can reduce ADHD symptoms (Salehinejad et al., 2020) and improve cognitive and behavioural skills such as inhibitory control and information processing (Nejati et al., 2022)—both of which are critical for academic success and the prevention of school failure.

tDCS has been consistently shown to be safe across healthy individuals, vulnerable groups, and ADHD populations (Salehinejad et al., 2020). Promising findings in tasks related to learning, combined with improvements in attention and executive functions, suggest that tDCS could serve as a valuable option for boosting intellectual as well as physical task performance.

3.3 fNIRS Hyperscanning

Learning outcomes are shaped not only by students' cognitive abilities but also by the quality of their social interactions with peers and teachers. Neurotechnological tools now make it possible to measure and interpret synchrony between individuals, including brain activity, an approach known as *hyperscanning*. Informally described as testing whether people are "on the same wavelength," hyperscanning records neural activity from multiple participants simultaneously to examine interpersonal coherence. While it has been used in studying real-world social interactions, its application to education remains limited.

Research supports the potential value of this approach. A meta-analysis by Zhang et al. (2022) found a positive association between neural synchrony and successful learning outcomes, encouraging further integration in education.

Among the most promising tools for hyperscanning is *functional near-infrared spectroscopy* (fNIRS), which addresses practical challenges such as motion sensitivity and flexibility in experimental design, offering advantages over EEG (Janssen et al., 2021). fNIRS has already been applied to ADHD research, confirming hypoactivation in the right prefrontal cortex during basic cognitive tasks such as Go/No-Go, Stroop, and Oddball (Gossé et al., 2021). Furthermore, hyperscanning with fNIRS has been used to study attention in ADHD and to explore brain synchrony in neurodiverse populations, including individuals with autism spectrum disorders (Kruppa et al., 2021).

4. LIMITATIONS OF THE STUDY

Although this study provides valuable theoretical perspectives on the role of neuroeducation in classroom practices, several limitations should be acknowledged.

Firstly, the research relies mainly on a review of existing literature rather than direct classroom-based experiments, which restricts the ability to draw firm conclusions about the practical implementation.

Secondly, the 20-item assessment tool developed has not yet undergone large-scale validation across diverse educational contexts, raising questions about its generalizability and reliability.

Thirdly, the potential selection bias may exist in the reviewed literature, as interpretations of neuroscience findings often differ across studies and fields of study.

Taken together, these limitations highlight the need for future empirical research, wider validation of assessment tools, and stronger interdisciplinary collaboration to advance effective applications of neuroscience in education.

5. CONCLUSIONS

This study offers a broad overview of neuroeducation and its possible influence on classroom teaching, while also presenting a practical tool to assess teachers' readiness to adopt its principles. Neuroeducation stands as a promising interdisciplinary field that integrates insights from neuroscience, psychology, and education in order to improve learning and teaching. By understanding how the brain acquires and retains knowledge, educators can design more effective instructional strategies, foster supportive environments, and address students' diverse cognitive and emotional needs.

A successful adoption of neuroeducation, however, requires more than a theoretical understanding. Teachers must be able to translate the concepts of brain function, emotional regulation, and motivation into evidence-based classroom practices.

These findings underline the importance of designing accessible and comprehensive professional development programs that provide both theoretical grounding and practical strategies for classroom application. With adequate institutional support, educators can adopt neuroscience-informed practices that enhance engagement, motivation, and achievement. Ultimately, embedding neuroeducation into teacher training and pedagogy could foster a more adaptive, inclusive, and effective educational system.

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