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Neuroeducation and neuromyths: A critical analysis of pseudoscientific beliefs in education

Neuroeducación y neuromitos: análisis crítico de las creencias pseudocientíficas en el ámbito educativo

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Abstract

This article examines the phenomenon of neuromyths—misconceptions about the brain and its relationship with learning—which, despite being refuted by scientific evidence, continue to be accepted by teachers, prospective educators, and society at large. Among the most widespread neuromyths are the belief in dominant learning styles, the idea that we only use 10 % of our brain, and the classification of individuals based on hemispheric dominance. These myths, lacking scientific foundation, negatively influence educational practices and may hinder student development. The persistence of programs such as *Brain Gym* and others—claiming to enhance cognitive performance without empirical support—is also addressed. The article concludes by underscoring the need to confront the presence of these neuromyths in Education by promoting scientific literacy among teachers at all educational levels, with the aim of improving learning quality. Furthermore, a critical analysis of the approach known as neuroeducation is presented, highlighting its limitations and associated risks, as well as its potential contributions. In this context, the article advocates for a rigorous approach to educational practice through the adoption of methods grounded in scientific evidence.

Keywords: neuromyths; neuroeducation; scientific literacy; pseudoscience in Education; evidence-based educational practice; teacher training.

Resumen

Este artículo examina el fenómeno de los neuromitos, creencias erróneas sobre el cerebro y su relación con el aprendizaje que, a pesar de la evidencia científica que las refuta, siguen siendo aceptadas por los docentes, futuros maestros y la sociedad en general. Entre los neuromitos más comunes destacan la creencia en estilos de aprendizaje dominantes, la idea de que solo utilizamos el 10 % de nuestro cerebro y la clasificación de las personas según la dominancia hemisférica. Estos mitos, que carecen de base científica, influyen negativamente en las prácticas educativas y pueden limitar el desarrollo de los estudiantes. Asimismo, se aborda la persistencia de programas como *Brain Gym* y otros, que afirman mejorar el rendimiento

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cognitivo sin respaldo científico. El artículo concluye subrayando la necesidad de abordar la presencia de estos neuromitos en la Educación, promoviendo la alfabetización científica entre los docentes en cualquier nivel educativo para optimizar la calidad del aprendizaje. Asimismo, se presenta un análisis crítico del enfoque conocido como neuroeducación, destacando sus limitaciones y riesgos asociados, así como sus aportes potenciales. En este contexto, se aboga por una aproximación rigurosa a la práctica educativa mediante la adopción de métodos fundamentados en la evidencia científica.

Palabras clave: neuromitos; neuroeducación; alfabetización científica; pseudociencia en la Educación; práctica educativa basada en evidencias; formación del profesorado.

1. Introduction

Over the last decades, the scientific community has shown increasing interest in analyzing the phenomenon of neuromyths, that is, widely disseminated misconceptions about the brain and its involvement in educational processes (Salgado *et al*, 1993; Ruhaak & Cook, 2018; Hughes *et al*, 2020; Rousseau, 2024). Recent systematic reviews (Torrijos-Muelas *et al*, 2021; Rodríguez *et al*, 2024) compiled data showing that, in most studies, up to 60% of participants accepted as true statements that are, in fact, neuromyths. One of the best-known examples is the idea that each person has a dominant learning style (Kirschner, 2017, Nancekivell *et al*, 2020). Research conducted across multiple countries has revealed the widespread presence of these myths among diverse populations, such as in-service teachers, pre-service teachers, and individuals from the general public lacking specific training (Khramova *et al*, 2023; Novak-Geiger, 2023).

In a landmark study, Dekker *et al* (2012) assessed the degree of acceptance of neuroscientific concepts among in-service teachers in the United Kingdom and the Netherlands using a 32-item questionnaire. These were divided into two types: items that reflected scientifically validated knowledge (known as "neurofacts") and others that contained widespread misconceptions in the educational field, that is, neuromyths. A prominent example of the latter is the statement that "individuals learn better when instruction is tailored to their preferred learning style (visual, auditory or kinesthetic)". (Pashler *et al*, 2008; Papadatou-Pastou *et al*, 2021). More recent studies carried out in various countries have replicated these results, showing that between 40% and 60% of teachers continue to believe statements that have no scientific basis (Fuentes & Risso, 2015; Ferrero *et al*, 2016; Medel & Camacho, 2019; Rodríguez *et al*, 2024). This persistence of neuromyths highlights the urgent need to strengthen scientific literacy among education professionals at all educational levels, including university lecturers. It is not only a matter of avoiding ineffective pedagogical practices, but also of preventing the adoption of ill-founded educational policies, as has occurred, for example, with the promotion of programs such as *Brain Gym*, despite the absence of solid scientific evidence to support this (Romero Naranjo, 2024).

One of the proposals put forward by Dekker *et al* (2012) involves increasing teacher training on how the brain works and on the processes related to learning. In their study, the authors also examined whether there was a relationship between general knowledge about neuroscience—measured through a lower error rate on scientifically correct statements (neurofacts)—and adherence to neuromyths. Unexpectedly, they observed that in-service teachers who made fewer mistakes on neurofacts tended, at the same time, to endorse more neuromyths. In other words, those who appeared to have greater neuroscientific knowledge also showed greater susceptibility to false beliefs. This pattern has been replicated in subsequent studies (Gleichgerrcht *et al*, 2015; Ferrero *et al*, 2016; Horvath *et al*, 2018).

By contrast, research conducted with prospective teachers (in initial teacher education) indicates an opposite trend: as their accuracy on neurofacts improves, the acceptance of neuromyths decreases (Ching *et al*, 2020). In this regard, training interventions aimed at improving teachers' understanding of neuroscience have been proposed as a preventive strategy. However, the results obtained so far are contradictory: some studies have concluded that such interventions have little or no impact on reducing erroneous beliefs (Rousseau, 2024), whereas others report positive but limited effects (Caballero & Llorent, 2022). Thus, neuromyths continue to be a persistent problem in education, and the most effective responses to debunk them are still under evaluation. For more than two decades, the Organization for Economic Cooperation and Development (OECD) has been warning that, alongside solid findings in neuroscience, there are "neuromyths" circulating in education: popular beliefs that simplify or distort the evidence about the brain. In its 2002 report (*Understanding the Brain*), the OECD (2002) devoted a specific section to "Neuromythologies" (4.6) and explicitly distinguished between what is well established, what is probable, speculation, and popular misconceptions. In 2007, in *The Birth of a Learning Science*, the OECD (2007) once again refuted neuromyths and documented that in educational communities "a vast array of ideas of varying value and substance circulate," from scientifically based approaches to neuromyths such as hemispheric "learning styles," noting further that teachers feel vulnerable to these supposed experts and are calling for training. These neuromyths distort pedagogical and educational policy decisions, with impacts such as inadequate resource allocation, creating barriers to inclusion, replacing good practices with seductive but unfounded "neuro" interventions, or eroding trust in neuroscience-education collaboration.

In light of these persistent institutional warnings (2002-2007), it is scientifically and socially relevant to define and measure the presence of neuromyths in specific populations (trainee and practicing teachers, management teams), identify their predictors (sources of information, training received, exposure to "neuro" materials), and to test critical neuroeducational literacy interventions. The OECD (2007) already recommended initial training and continuing with a critical approach and the creation of bridge profiles that facilitate dialogue between research and the classroom.

This paper aims to examine the most persistent neuromyths in education, challenging popular but incorrect beliefs about the brain and learning processes. Through a critical review, it analyses the causes of their dissemination, their impact on teaching practices and the importance of promoting education based on scientific evidence. The article seeks to promote scientific literacy among teachers and to prevent the adoption of ineffective pedagogical approaches, particularly those grounded in widely accepted myths that are not supported by research. Likewise, it offers a critical examination of the neuroeducation paradigm, highlighting both its potential benefits and its inherent weaknesses and dangers. From this perspective, it emphasizes the relevance of orienting pedagogical work towards models grounded in empirical evidence and in verified results, thereby encouraging the adoption of educational approaches based on data.

2. Widespread neuromyths in education

2.1. Students learn better when they are taught according to their learning style (visual, auditory, kinesthetic)

This neuromyth is based on misinterpreted theories of individual differences in learning, popularized in the 1970s and 1980s. Drawing on models such as that of David Kolb (1984), experiential learning theory identified four learning styles: convergent, divergent, assimilating and accommodating. Although Kolb's model was originally concerned with how individuals process experience in learning, it was subsequently oversimplified and misinterpreted, leading to the assumption that learners possess fixed learning styles that must be accommodated to optimize learning outcomes. Another influential model was VARK, developed by Fleming y

Mills (1992), which classifies students as visual, auditory, read/write and kinesthetic. Although it was designed as a tool to help students understand their study preferences, VARK was widely adopted in educational settings as a guide for adapting teaching, despite the lack of empirical evidence supporting its effectiveness. It has been widely disseminated in teacher-training manuals (Furey, 2020) and commercial materials (Cherry, 2024) because it is intuitive and appealing to teaching staff. The consequence is that it encourages the design of ineffective materials, wasting time and resources without producing real improvements in learning (Garvida, 2024; Melzner & Kappes, 2024).

2.2. The myth that we only use 10% of our brain

One of the most persistent and widely disseminated neuromyths in popular culture is the belief that human beings use only 10% of their brain. This claim, devoid of scientific foundation, has been erroneously attributed to figures such as William James, who in fact wrote that most people "do not reach their full mental potential", but never specified an exact percentage (James, 1907). The myth has also been linked to misinterpretations of nineteenth-century neuroscientific research, when the functionality of many brain regions was still poorly understood.[1]

In reality, current neuroscientific evidence shows that virtually all regions of the brain have an identifiable function and are active at some point, even during sleep (Badenoch, 2008). Neuroimaging studies, such as those using functional magnetic resonance imaging (fMRI), reveal patterns of activation distributed across almost the entire brain during everyday tasks, from speaking to remembering or planning (Raichle *et al,* 2001). Likewise, localized brain damage, even in small areas, can have devastating consequences, which completely contradicts the notion that 90% of the brain is "unused" or expendable.

Nonetheless, despite its age, this neuromyth persists. Its endurance has been fueled by the appealing message that we possess a "hidden potential" waiting to be unlocked, which has been exploited by cinema—as in the films *Lucy* (Besson, 2014) and *Limitless* (Burger, 2011)—and by the personal-development and self-help industry (Dispenza, 2014). This idea has served as a justification for the promotion of pseudoscientific products and programs -such as pharmacological supplements, "mental" exercises or technologies supposedly designed to "activate the rest of the brain"- without any empirical backing (Brown *et al*, 2014).

Belief in this neuromyth is not only erroneous but potentially harmful, as it diverts resources and attention away from educational or therapeutic interventions that are based on evidence. It also fosters unrealistic expectations about learning and brain plasticity. According to recent studies, between 50% and 70% of pre-service and in-service teachers believe that this statement is true, which highlights the urgency of strengthening neuroscience education in educational contexts (Dekker *et al,* 2012; Howard-Jones, 2014).

2.3. The neuromyth of hemispheric dominance

The myth that people are "more logical" or "more creative" depending on whether the left or right hemisphere of the brain is dominant has no scientific basis, even though it draws on genuine research on cerebral lateralization. This lateralization means that certain cognitive functions tend to be more localized in one hemisphere (for example, language in the left hemisphere in most right-handed individuals). However, this specialization does not imply that one hemisphere "dominates" personality, thinking style or learning ability. This neuromyth continues to be promoted by teacher-training materials, outdated educational resources and social-media posts that offer eye-catching quizzes such as "Are you more left-brained or right-brained?" It's persistence is partly due to its intuitive and simplistic appeal, providing a seductive explanation for individual differences.

This neuromyth has its roots in the work of Roger Sperry and Michael Gazzaniga in the 1960s and 1970s with "split-brain" patients (Gazzaniga *et al*, 1962), whose corpus callosum had been severed to treat severe epilepsy. Their studies demonstrated certain functional asymmetries in specific tasks. However, these findings were distorted in popular science

communication, particularly in self-help books and oversimplified educational materials. As Gazzaniga (2005) explains, although the hemispheres display specializations, the human brain functions in a highly interconnected manner, and any complex cognitive activity involves both hemispheres simultaneously.

Functional neuroimaging studies (fMRI, PET) have shown that both creative and analytical tasks recruit areas distributed across both hemispheres. For example, Kounios and Beeman (2014) found that creative problem solving activates bilateral networks, including areas in the left hemisphere. Similarly, linguistic tasks, traditionally associated with the left hemisphere, also require contextual and emotional processing that involves right-hemisphere regions. An extensive review by Nielsen *et al* (2013), based on more than 1,000 brain scans, concluded that there is no evidence that some people are "left-brained" or "right-brained", and that neural networks are widely distributed. However, the uncritical acceptance of this neuromyth can have various educational implications affecting both curriculum design and teaching practice. The following are particularly noteworthy:

(a) Inadequate identification of students' profiles. Belief in hemispheric dominance can lead to labelling students as "analytical" or "creative", which restricts their exposure to a variety of learning experiences. Such classification may limit the development of skills in areas that do not align with the supposed dominance, thereby hindering a holistic education.

(b) Design of educational programs without scientific grounding. Some educational programs are based on the idea of stimulating a specific hemisphere to enhance certain abilities, such as creativity or logical reasoning. However, research has shown that these interventions lack a scientific basis and do not produce the expected results (Alferink & Farmer-Dougan, 2010).

(c) Misuse of available educational time and resources. Implementing pedagogical strategies grounded in this neuromyth may lead to an inefficient allocation of resources and time, diverting attention from teaching methods supported by empirical evidence.

(d) Reinforcement of gender and ability stereotypes. Associating certain abilities with a specific hemisphere can reinforce gender stereotypes, such as the notion that women are more creative and men are more logical, thereby perpetuating inequalities in access to and motivation for certain disciplines (Bian *et al*, 2017).

(e) Resistance to evidence-based pedagogical approaches. The persistence of this neuromyth may foster resistance among educators and professionals to evidence-based teaching approaches, as such approaches contradict entrenched beliefs about learning and cognition.

2.4. "Brain Gym" improves cognitive performance

The *Brain Gym* program, created in the 1980s by Paul and Gail Dennison, claims that certain bodily movements (such as crossing the arms to touch the nose or massaging specific points) activate brain areas and facilitate learning, attention and memory (Dennison & Dennison, 1989). These ideas are based on erroneous or simplistic interpretations of neuroscience, such as hemispheric integration or the activation of specific brain regions (Hyatt, 2007). Although general physical exercise does indeed have cognitive benefits (Hillman *et al*, 2014), *Brain Gym*'s specific claims lack empirical support and have been criticized for their pseudoscientific nature (Waterhouse, 2006; Stephenson, 2009). The main criticisms are: (a) absence of solid empirical evidence (Stephenson, 2009); (b) unfounded neurological claims (Howard-Jones, 2014); and (c) confusion between correlation and causation. While movement can improve cognition, there is no evidence that symbolic gestures have such an effect.

Despite the lack of evidence, *Brain Gym* has been adopted in numerous school systems, promoted by its ease of application, its seemingly "neuroscientific" veneer and the belief that movement always favors learning (Dekker *et al*, 2012). Recent studies document its use among teachers, especially where training in neuroscience is limited. More than half of teachers continue to endorse the program (Grospietsch & Mayer, 2021). Other programs, such as *LearningRx*, have also been criticized by the United States Federal Trade Commission (Federal-

Trade-Commission, 2016) for claiming, without support, that they improve conditions such as ADHD or dyslexia, despite scant independent scientific evidence.

2.5. "Fast ForWord" improves linguistic and cognitive skills

Another educational product marketed under the label of neuroeducation is the so-called *Fast ForWord* program, a computer-based educational intervention designed to improve linguistic and cognitive skills in students with learning difficulties, particularly in reading and auditory processing. Developed by Scientific Learning Corporation and grounded in research on research in the neuroscience of language (Merzenich *et al*, 1996), the program became popular in school and clinical contexts under the promise that exercising certain auditory and cognitive abilities through software could "re-wire" the brain and boost academic performance. However, despite its initial grounding in plausible neuroscientific findings, multiple independent studies have questioned its effectiveness and empirical basis (Borman *et al,* 2009; Strong *et al*, 2011).

Fast ForWord is based on the theory that some reading problems stem from deficits in rapid auditory processing and that brain plasticity can be stimulated through specific computerized exercises. The games and tasks offered by the program seek to improve attention, working memory, phonological discrimination and other underlying cognitive functions. Although its initial development was supported by neuroscientists such as Michael Merzenich and Paula Tallal, subsequent research has yielded inconsistent results for various reasons (Strong *et al*, 2011).

A first criticism relates to the weak or non-replicable evidence for *Fast ForWord*. An independent review by the What Works Clearinghouse (2013) concluded that *Fast ForWord* has no significant effects on improving reading among students with learning difficulties. Most of the studies that do report positive effects have been carried out by researchers affiliated with the program itself, which introduces potential bias (Strong *et al*, 2011).

Moreover, it has been shown that its results are no better than those of other, more traditional interventions. The meta-analytic review by Strong *et al* (2011) and the subsequent analysis by Borman *et al* (2009) found that students who used *Fast ForWord* did not improve more than those receiving conventional reading instruction or one-to-one tutoring. This suggests that the program's "neuro" component does not add any significant differential value.

Criticism has also been directed at its theoretical framework. Various authors have argued that the theory of a "rapid auditory processing deficit" as the primary cause of dyslexia or reading difficulties is not conclusive (Ramus *et al*, 2013). Likewise, the idea that cognitive games can produce generalized improvements in complex academic skills has been refuted by recent research (Sala & Gobet, 2019). Simons *et al* (2016) point out that programmed such as *Fast ForWord* profit from the commercial appeal of neuroscience ("neuro-marketing"), yet do not meet basic standards of scientific replication. The improvements they report do not hold up in double-blind studies and are not consistent across populations.

Despite its neuroscientific packaging and its presence in many educational institutions, *Fast ForWord* lacks solid empirical support that would justify its systematic implementation as a tool for improving learning. Most independent studies show minimal or null effects on academic skills such as reading and text comprehension. In addition, its high cost and the diversion of resources towards programmes of dubious benefit raise ethical and pedagogical concerns. It is therefore preferable to prioritise interventions with strong evidence, which include teacher support, a real educational context and rigorous evaluation, instead of relying on unvalidated technological solutions.

The case of *Brain Gym* illustrates how the appearance of a scientific basis, attractive technical language and a simple narrative can contribute to the adoption of neuromyths in education. It is crucial that education authorities, teachers and teacher-trainers receive critical training in educational neuroscience so that they can distinguish between valid and pseudoscientific proposals.

3. Neuroeducation: between science and myths

In recent years, neuroeducation or educational neuroscience (Bhargava & Ramadas, 2022; Pradeep *et al*, 2024) has attracted growing interest because of its promise to merge neuroscience, psychology and pedagogy in order to optimize educational processes. It aims to use knowledge about the human brain to improve teaching and learning. However, despite its increasing presence in the media and in educational discourse, several experts within the scientific community have expressed doubts about the soundness of its foundations, the correct interpretation of its findings and the proliferation of misconceptions stemming from this approach. Some authors, such as Tokuhama-Espinosa (2011), have defended its theoretical and applied value. Nevertheless, from the outset, warnings were raised about the risks of a "hasty translation" from the laboratory to the classroom (Bruer, 1997). His well-known article "Education and the Brain: A Bridge Too Far" drew attention to the limited practical usefulness of applying neurological findings directly to educational contexts without mediation through in-depth knowledge of cognitive psychology.

3.1. Some fundamental criticisms of neuroeducation

Although neuroeducation has generated considerable interest because of its apparent potential to improve teaching by integrating knowledge about the brain, it has also been subject to criticism. Analyzing these limitations is essential for moving towards a more rigorous pedagogy that is truly useful for the educational field. The following are some of the main criticisms directed at the neuroeducational approach, intending to reflect on its limits and current challenges.

Proliferation of neuromyths. One of the major side effects of neuroeducation has been the spread of neuromyths—misconceptions about the brain that are presented as scientific. Well-known examples have been discussed above (Dekker *et al*, 2012; Torrijos-Muelas *et al*, 2021).

Misapplication of neurological findings. One of the main points of criticism directed at neuroeducation concerns the inappropriate transfer of neuroscientific findings to education. Neuroscience studies are often conducted under highly controlled laboratory conditions using technologies such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG). While these techniques allow researchers to identify neural correlates of certain cognitive processes, they do not guarantee direct applicability to real classroom settings. Such studies usually involve small, homogeneous and unrepresentative samples of the general student population, which limits the generalization of results to the diversity present in schools (Bruer, 1997; Bowers, 2016).

Methodological criticism intensifies when we observe a direct translation from results obtained through neuroimaging techniques to pedagogical proposals, without going through fundamental intermediate phases such as psychological validation or empirical evaluation in real school environments. This epistemological "leap" has been described by several authors as an example of neuro-reductionism or neuro-fetishism (Castaño, 2020; Dekker & Jolles, 2015), whereby disproportionate authority is granted to neuroscience simply because it is linked to the study of the brain, even when it lacks direct relevance for educational practice.

This practice can also create unrealistic expectations among teachers and policymakers by suggesting that neuroscience-based interventions are inherently effective, despite evidence showing they do not reliably improve learning or academic outcomes (Howard-Jones, 2014; Thomas *et al*, 2019). This may divert resources and attention away from pedagogical practices already validated by educational research, thereby contributing to the spread of neuromyths.

Consequently, it is essential to promote robust interdisciplinary articulation between neuroscience, cognitive psychology and the educational sciences, ensuring adherence to rigorous methodological standards and an interpretation of results consistent with real educational contexts. This integrative approach is a necessary condition for translating advances in neuroscience into valid, effective and empirically supported teaching practices.

Appropriation for commercial and pseudoscientific purposes. In addition to the cases already mentioned, such as *Brain Gym* and *Fast ForWord*, recent years have seen a further proliferation of educational products marketed as "brain-based" that lack rigorous scientific support. These products, often endorsed by anecdotal testimonials or low-quality studies, are sold in the form of digital applications, cognitive-stimulation programs, personalized learning platforms or teaching materials with supposed neuro-activating properties. Their presence in schools has grown, fueled by the pressure of the educational-technology (edtech) market and by the perception that anything labelled "neuro" guarantees innovation and effectiveness.

Recent research warns of the risks posed by this trend. Tokuhama-Espinosa (2021), one of the most prominent voices in the field of neuroeducation, notes that many programs advertised as neuroscientifically validated do not meet the minimum criteria of scientific evidence. Similarly, a recent report by the Education Endowment Foundation (2023) warns that many initiatives claiming "neuronal improvements" have no significant effects on academic outcomes when evaluated independently. This is consistent with findings by Van Atteveldt *et al* (2021), who highlight that adopting interventions without empirical validation can create an illusion of effectiveness, masking their lack of real impact.

Several prominent neuroscientists, such as Ignacio Morgado, have expressed a critical stance towards the excessive and, at times, unfounded use of the prefix neuro in fields outside basic or clinical neuroscience. This is the case with terms such as neuro-architecture, neuromarketing and, in particular, neuroeducation, which, although they seek to bring a scientific perspective to the study of human behavior in applied contexts, often lack a solid empirical foundation from the standpoint of neuroscience. As Morgado (2025) points out, many of the claims presented at conferences or in popular texts as recent neuroscientific discoveries applied to education—for example, the idea that "motivation is essential for learning" (Congreso Nacional de Neurociencia Aplicada a la Educación, 2017)—are in fact principles that have been well established for decades by scientific psychology, especially by theories of learning and motivation. This tendency to endow traditional concepts with added value by "re-labelling" them with neuroscientific terminology may generate a false sense of novelty or greater scientific rigor when, in reality, they are already integrated into the corpus of psychology. From this standpoint, Morgado stresses that, although neuroscience can enrich our understanding of the cognitive and affective processes involved in learning, its contribution should be understood as complementary rather than as a substitute for the theoretical and empirical frameworks that have historically guided educational practice. My position is that useful contributions from neuroscience to education tend to be indirect and mediated by the science of learning, not immediate methodological "revolutions"; that is why prudence and dialogue with psychology are essential. Consequently, I endorse caution in the face of the proliferation of "neurodisciplines" (neuromarketing, neuroarchitecture, neuroeducation, neurolinguistic programming). We understand that it is necessary to promote an integrative and critical approach that avoids biological reductionism and recognizes the complexity of educational phenomena beyond brain activity. At a practical level, the uncritical acceptance of such proposals can divert institutional resources and create confusion among teachers and families, undermining trust in educational research. Moreover, some of these products incorporate claims that reinforce widely discredited neuromyths, such as the idea that we use only 10% of our brain or that stimulating one hemisphere or the other according to learning styles enhances performance. As noted above, these beliefs have been refuted in the scientific literature (Dekker *et al*, 2012; Howard-Jones, 2014), yet they continue to be used as selling points.

It is therefore urgent to establish stricter filters for introducing neuroeducational programs into schools, promoting independent evaluation of their effectiveness and adherence to solid scientific standards. In addition, greater training in neuro-scientific literacy is needed for teachers, enabling them to distinguish genuine advances from commercially motivated strategies disguised as science (Alcaide-Padial *et al*, 2025; Peregrina-Nievas y Gallardo-Montes, 2023). Initiatives such as the Educational Neuroscience Hub (Royal Society, 2022)

and collaborations among international research networks are beginning to establish quality frameworks for distinguishing evidence-based practices from those that, while attractive, lack real scientific grounding.

Despite its limitations, the neuroeducational approach has helped rekindle interest in the science of learning. Some neuroscientific findings, particularly in areas such as memory, attention, emotion and neuroplasticity, have proved useful when articulated with robust psychological and pedagogical frameworks (Carbone y Diekelmann, 2024). Various academic forums (Thomas *et al*, 2019) acknowledge that neuroeducation can contribute valuably to education, provided certain fundamental criteria are met: its proposals must be grounded in robust, replicable scientific evidence; they must be integrated into well-founded educational approaches; they must avoid reductionist simplifications of brain functioning; and teachers must receive rigorous training in critical neuro-scientific literacy.

3.2. Empirical Evidence

Recent studies have explored the impact of training programs based on neuroeducation (Rodríguez *et al*,2024; Rodríguez, 2024). A quasi-experimental study conducted in Spain evaluated a two-year teacher-training program in neuroeducation, observing improvements in reading, mathematics and socio-emotional competences among secondary-school students. Similarly, a study at Jaume I University analyzed the effect of a neuro-didactics program on the psychological capital of student teachers, finding increases in motivation and academic engagement (Segarra *et al*, 2015; Caballero & Llorent, 2022; Ventura *et al,* 2024). In the field of early childhood education, a systematic review highlighted the growing integration of neuroscience into pedagogical practices in early childhood in Ibero-America, revealing an increase in research applying neurobiological knowledge to enhance early learning (Llatance *et al*, 2024), although its reach is still limited (Mondéjar *et al*, 2023).

4. Limitations and criticisms

Despite these advances, neuroeducation faces criticism related to the transfer of neuroscientific findings to the classroom. Many studies are conducted in controlled laboratory settings, which makes their direct application to real educational contexts difficult. Moreover, the lack of specific training in neuroscience among teachers can lead to the adoption of neuromyths or practices without empirical support (Carballo Márquez, 2023).

Another challenge is the overestimation of neuroeducation as a universal solution to complex educational problems. Implementing strategies based on neuroscience requires careful adaptation to the educational context and close collaboration between researchers and education professionals (Carballo Márquez, 2023). Integrating neuroeducation into educational practice raises a series of ethical considerations that require careful attention, particularly regarding the use of neurotechnologies and the protection of students' data privacy. As neuroscience advances and new tools and techniques emerge for monitoring and modifying the brain—such as neurotechnologies and brain-stimulation technologies—legitimate concerns arise about their implementation in educational environments. These technologies may involve constant monitoring of students' brain activity, which raises concerns about data privacy and informed consent. Ethical frameworks must be adapted to educational realities to ensure that students are not subjected to invasive surveillance or non-consensual manipulation (García-Martínez *et al*, 2023).

The application of neuroeducational interventions, such as devices for non-invasive brain stimulation (tDCS) or technologies for real-time brain monitoring, must be managed ethically, respecting students' autonomy and the principle of non-maleficence. Clear guidelines are also needed for the collection, storage and use of students' neurological data, ensuring that they are not used inappropriately or for unauthorized purposes. Parents, students and teachers should be clearly informed about the risks and benefits of these interventions, as well as the measures in place to protect privacy.

In addition to privacy concerns, ethical debates also arise regarding equity and access to neuroeducational technologies. In many cases, these technologies are expensive and available only in specific educational contexts, which could widen gaps in access to quality education based on neuroscience. Educational policies and regulatory frameworks must ensure that neuroeducation does not become a factor of inequality but is instead used to promote equal access to learning opportunities.

Recent studies have highlighted the importance of integrating ethical principles into neuroeducation (Codina, 2015; García-Martínez *et al*, 2023; Staudegger y Zandonella, 2024). According to a report by the British Psychological Society (2021), it is necessary to promote a multidisciplinary approach to research and application in neuroeducation that involves neuroscientists, educators, psychologists and ethics experts. This approach must prioritize safety, informed consent and the protection of human rights throughout the implementation of neurological technologies in classrooms.

Therefore, neuroeducation must be grounded in rigorous ethical reflection and in regulations that ensure respect for students' rights and wellbeing in any intervention based on neuroscientific knowledge. Within this framework, the protection of privacy and the prevention of misuse of neurological data are priorities. It is also essential to promote ongoing, critical and evidence-based teacher training that equips teachers to apply the principles of neuroeducation in an informed and responsible manner.

5. Conclusions

The rise of neuroeducation has generated significant expectations about the possibility of transforming educational practices through knowledge of the brain. However, as this critical review has attempted to show, the field is still in an early stage and faces major epistemological and methodological limitations. The proliferation of neuromyths, even among education professionals with scientific training, clearly demonstrates the urgent need to improve teachers' neuro-scientific literacy and to adopt a critical stance towards proposals that link neuroscience and education.

Neuroeducation will only consolidate itself as a legitimate field if its proposals are integrated into robust pedagogical frameworks and supported by replicable findings obtained through rigorous methodologies. It is crucial to avoid reductionist approaches and premature extrapolations from neurobiological data to educational practice without intermediate validation through educational research.

The pedagogical proposal based on neuroeducation through universal design for learning (UDL) is intriguing, and its incorporation must be based on criteria grounded in solid pedagogical frameworks, rigorous evaluation, and a rejection of reductionism (Durgungoz & Durgungoz, 2025; Roski *et al*, 2024). UDL can function as a design scaffold—not as a "direct translation" of neurobiological findings—because its theoretical justification is based on principles of learning variability linked to brain networks (affective, recognition, and strategic) and instructional design guidelines, but this link operates as a connecting hypothesis and not as conclusive evidence. In this sense, the dialogue between neuroeducation and UDL must be articulated and offer an inclusive operationalization useful for teaching planning and reflection, but the adoption of these guidelines should be read as a design hypothesis subject to educational verification in context (Elizondo, 2022). The empirical evidence accumulated on the effectiveness of UDL is promising but still heterogeneous and limited: recent systematic reviews and meta-analyses find positive effects on certain outcomes, while emphasizing the need for more controlled studies and consistent reports on implementation (Almeqdad *et al*, 2023). This "projection" will only be legitimate if it is integrated into action research cycles (design-implementation-evaluation) and accompanied by neuroscientific literacy that allows teachers to avoid neuromyths and hasty extrapolations (Torrijos-Muelas *et al,* 2021). UDL can be a useful pedagogical framework for guiding equitable and evidence-based practices, provided that its use is subordinate to replicable evidence.

Likewise, sustained interdisciplinary collaboration is needed among neuroscientists, educational psychologists and pedagogues to enable the translation of knowledge about the brain into educational interventions that are truly useful and context-sensitive. Until this empirical and methodological basis is consolidated, the priorities of the education system should focus on factors more directly related to improving learning, such as equity, evidence-based teacher training and the development of effective teaching practices. Neuroeducation does have potential, but its value will depend on our ability to distinguish rigorous scientific knowledge from pseudoscientific trends (Bosada Morán, 2023) and to adopt a critical, ethical and evidence-based approach to its implementation in schools.

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Notes

[1] The functionality of large association regions remains an active area of research and is not yet fully understood (Menon, 2023).

Author biography

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