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Neuroedumyhts: A Contribution from Socioneuroscience to the Right to Education for All

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Abstract

Scientific literature about neuromyths has proliferated in the last few years. However, there is a gap of knowledge around neuroedumyths. While neuromyths are based on hoaxes about the brain, neuroedumyths use neuroscientific concepts but state consequences for education that are false. This article presents, for the first time, research about neuroedumyths among teachers. This study has applied the innovative methodology of Public Lectures' Debates Analytics (PLDA), in its ex-post modality. This has meant the analysis, by the twelve participants interviewed in this research, of the conclusions of public lectures' debates on neuroscience and education. The results show the presence of four neuroedumyths among teachers: The brain needs to be bored to develop; Violence resides in masculine genes; Brain develops almost completely the first three years of life; and There are right-hemisphere students and left-hemisphere students. While neuromyths have been spread among teachers by trainers specialized in education but lacking scientific information about neuroscience, neuroedumyths have been spread among teachers by neuroscientists lacking scientific information on education. Differently to some previous studies which approached this problem as teachers' errors or ignorance, the results of our study show that the problem is the errors of some teachers' trainers.

Keywords: neuroedumyths, socioneuroscience, neuromyths, teachers, families

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Neuroedumitos: Una Contribución de la Socioneurociencia para el Derecho a la Educación de Todas y Todos

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Resumen

La literatura científica sobre neuromitos ha proliferado en los últimos años. Pero existe un vacío en torno a los neuroedumitos. Mientras que los neuromitos se basan en bulos sobre el cerebro, los neuroedumitos utilizan conceptos neurocientíficos, pero enuncian consecuencias para la educación que son falsas. Este artículo presenta, por primera vez, una investigación sobre neuroedumitos en el profesorado. Este estudio ha aplicado la innovadora metodología de Public Lectures' Debates Analytics (PLDA), en su modalidad ex-post. Esto ha supuesto el análisis, por parte de los doce participantes entrevistados en esta investigación, de las conclusiones de debates de conferencias públicas sobre neurociencia y educación. Los resultados muestran la presencia de cuatro neuroedumitos entre el profesorado. Mientras que los neuromitos han sido difundidos entre el profesorado por formadores especializados en educación pero que carecen de información científica sobre neurociencia, los neuroedumitos han sido difundidos entre el profesorado por neurocientíficos/as que carecen de información científica sobre educación. A diferencia de algunos estudios anteriores que enfocaban este problema como errores del profesorado, los resultados de nuestro estudio muestran que el problema son los errores de algunos formadores/as del profesorado.

Palabras clave: neuroedumitos, socioneurociencia, neuromitos, profesorado, familias

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The concept of neuromyth was created by Alan Crokart in the 1980s in the field of medicine. Since then, it has been a very useful contribution to different fields to avoid hoaxes about neuroscientific knowledge that can be negative for human beings (Dekker et al., 2012; Howard-Jones 2014; Ferrero et al., 2016; Im et al., 2018; Yfanty & Doukakis, 2021; Rousseau, 2021). In education, this concept has been much used since 2002, when the OECD published *Understanding the Brain: Towards a New Learning Science*. In that document, it was stated:

> The genesis of a neuromyth usually starts with a misunderstanding, a misreading and in some cases a deliberate warping of the scientifically established facts to make a relevant case for education or for other purposes. There are three popular myths discussed in this chapter: hemisphere dominance or specialisation, synaptic development and learning, "critical" periods, and enrichment (including the myth of birth to three) (OECD, 2002, p. 71).

The authors of this article consider the creation of the concept "neuromyth" and its implementation in education very positive, although we do not agree with its name. The name identifies myth in negative terms, as the opposite of scientific truth. In the history of humanity, myth and mythology have represented and represent much more.

The OECD concept of neuromyth for education focuses on misconceptions about concepts of neuroscience and their negative consequences for education (McIntosh & Ritchie, 2012). That is an important contribution. Nevertheless, neuroscientists who know scientific concepts in their field may also have misconceptions about education. Excellent neuroscientists who do not know the scientific literature about education, do not talk or write about what teachers should do in the classroom. However, some neuroscientists who have no success in neuroscience, explain well to teachers how the brain works but, in order to satisfy their education audience and readers, they tell teachers what they should do without having rigorous knowledge of scientific literature in education. For that reason, the concept of neuroedumyth is wider than the concept of neuromyth, as it includes any misconception about the relationship between neuroscience and education. Neuromyths in education, as they were defined by the OCDE, are a subset of neuroedumyths.

There is already very rich scientific literature about neuromyths among teachers. Since the OECD publication in 2002, new neuromyths have been identified and clarified. Excellent literature reviews on this topic have been published, and they have advanced the analysis of how neuromyths are generated. For instance, Torrijos-Muelas et al. (2020) point out the following:

> The findings present neuromyths as the consequence of a lack of scientific knowledge, a communicative gap between scientists and teachers, and the low-quality information sources consulted by teachers. In addition, the data on protectors and predictors of neuromyths is inconsistent (p. 1).

Despite such publications, there is a gap of knowledge on neuroedumyths. While the current studies on neuromyths analyze the misconceptions on the brain and their consequences for education (Dekker et al., 2012; Ferrero et al, 2016; Geake, 2008; Howard-Jones, 2014), there is almost no scientific research and publications about misconceptions in education generated by neuroscientists who talk and write about the consequences of neuroscientific knowledge for education. Some authors say that the solution will come from neuroeducation based on scientific bases from both neuroscience and pedagogy. But that perspective is mistaken because the study of education includes interdisciplinarity between pedagogy, psychology, sociology, and other social sciences.

In order to properly analyze the relationship between neuroscience and education, it is necessary to know the scientific evidence from neuroscience, from pedagogy, and from several other social sciences. This is the objective of socioneuroscience (Puigvert, Flecha et al., 2019; Racionero-Plaza et al., 2022), which has led to the elaboration of the concept of neuroedumyths (Flecha, 2017). Besides contributing to education, socioneuroscience provides a needed interdisciplinarity to neuroscience. Neuroscience has fruitfully used concepts from some trends of psychology, such as behaviorism. However, this reduction limits the contribution of neuroscience to the analysis of the human being and of society. This article is based on the interdisciplinary perspective of socioneuroscience, and in so being is one of the needed contributions to filling the aforementioned gap, contributing to

achieve positive social impact by improving the educational results of all students (Flecha et al., 2023).

Methods

The methodological choice for conducting this study was the communicative methodology. This research methodology has been the source of two of the main criteria of the current scientific research programme Horizon Europe: social impact and co-creation. Those criteria make it possible to continuously enrich the communicative methodology with new innovations (Bellavista et al., 2022), always looking to include new voices and new spaces.

A recent and fruitful innovation has been the creation of Social Media Analytics (SMA) in order to include the voices of citizens in social media. This has been the first step to develop the new methodological contribution named "Public Debates Analytics" (PDA). SMA is a modality of PDA. The research presented in this article is the first one to use another modality of PDA named Public Lectures Debates Analytics (PLDA). This contribution is a new methodological innovation which further enriches the communicative methodology, by widening the scientific analysis of citizens' voices to a new space: the debates in public lectures, and then contrasting them dialogically with the most relevant scientific literature about the matter discussed.

Co-creation needs to consider the voices of teachers in all spaces where they are expressed. In the debates following or included in public lectures, teachers express continuously their views about diverse issues, one of which is neuroscience and education. But communicative methodology is not just what people say without considering existing scientific evidence about the topic under discussion, but it implies egalitarian dialogue between citizens' voices and existing scientific evidence. PLDA is the scientific result of this dialogue that has powerful potential social impact. To not hinder the accomplishment of the objective of lectures in which hundreds and sometimes thousands of people participated, we took for this research the first of two possibilities: Ex-post PLDA. This means the analysis, by the twelve participants interviewed in this research, of the conclusions of the debates in public lectures. These participants signed the informed consent. In the future, a second possibility should be explored: to get the consent from all participants in the lectures (considering that some arrive later or leave

before it finishes) while not hindering the objective of the lectures and debates, which is the training of the participant teachers to ultimately improve the educational results of their students.

In the research reported in this article, the qualitative data emerged from interviews to twelve individuals who participated in seventeen lectures and in their debates; these lectures were given in different sites around Spain. Following the advice of the Ethical Committee, the identification of participants has been anonymized, also the names of the concrete sites where the lectures were face to face delivered. Although eight of the informers are now university professors, the twelve of them have been in the past or still are schoolteachers. Two of the authors of this article have been responsible for, in dialogue with the informers, contrasting the four neuroedumyths identified in the debates with most relevant scientific literature in neuroscience, like books by the Nobel Prize laureates, Santiago Ramon y Cajal, Rita Levi Montalcini, and Eric Kandel. For these authors, the knowledge of this literature has included chapter by chapter reading and discussion with other colleagues of books like "Principles of Neural Science".

Results

The informers shared their conclusions of the public lectures' debates attended, and these conclusions referred to four neuroedumyths. In what follows, each of the neuroedumyhts is presented and explained, and analyzed according to the informants' inputs.

Neuroedumyth 1: The Brain Needs to Be Bored to Develop

The informants concluded from their involvement in public lecture debates that one of the most common neuroedumyths taught in neuroscience and education training is the idea that children's and adolescents' brains need to be bored to develop. Participants shared that they had concluded from public lectures' debates that some trainers, while talking about neuroscience and education, mentioned that stress is very negative for the positive development of the human brain. Then, those trainers argued that stress is caused by emphasizing instrumental learning in schools, such as developing first notions of reading and writing in early childhood education or extending

learning time in schools to work on mathematics, language, or science. In doing so, trainers emphasized the idea that the amount of schoolwork and complexity of learning were the causes of students' stress. Consequently, they claimed that such intense schoolwork should be replaced with time for being bored. Nuria explained this by recalling one of her experiences:

> I remember very well the day when one of those trainers claimed that schoolwork produces toxic stress in the brain of children. That was after he said that stress is negative for the brain, which seemed to be right according to the readings that we had made of authors such as Eric Kandel. But right afterwards he stated, with no scientific reasoning in between, that such idea implied that school homework damages neural development.

From the discussions that took place in the lectures, some participants concluded that some teachers, after hearing some trainers state that "the brain needs to be bored to develop", had started planning new school schedules which included school time for children to get bored.

Even schools where children from the poorest families of the country have experienced educational success thanks to the implementation of Successful Educational Actions, which emphasize instrumental learning for all, have been the object of criticism based on this neuroedumyth. For instance, our informers shared about one of those schools being attacked in a public lecture debate by followers of the trainers who explain this neuroedumyth. Elisa, a teacher in a school applying Successful Educational Actions, a school which is raising the academic achievement of its students, shared that the attacked included the following:

> We were in the room where that talk was given, and it was known that in our school we apply Successful Educational Actions, that imply an emphasis on dedication of students to learn what is crucial in the curriculum and for their future success. This emphasis often involves the extension of the learning time in the school. The comment we received strongly in that talk was: "Boredom is necessary. Children are overstimulated nowadays".

Informers shared that this attacking position also used neuroedumyths to justify that the attackers were not overcoming inequalities in their schools and wanted the successful school to become like theirs. Elisa reports:

> The same people supporting those neuroedumyths, are not engaged in educational projects that are transforming school failure, that are helping children to excel in schools.

Nevertheless, teachers, families, and citizens in general now have more access to scientific evidence on both neuroscience and education. In this regard, another informant noted that in a public lecture, a trainer stated the idea that for the brain to develop, the child needs to be bored, which was supported by someone else in the audience who said that it was good to know that it is beneficial to be bored, because today parents have the false belief that children should be busy all day. Our informant shared with us that in the discussion of the public lecture, a third person from the audience intervened quoting top-level neuroscientists, concretely, Rita Levi, Kandel and Pascual-Leone, and said that these neuroscientists had shown the opposite: without cognitive challenge, there is no learning in the brain. Pere shared how important was that moment:

> A colleague raised her hand and shared quotations from the Nobel laurates in neuroscience and Pascual-Leone that clearly dismantled the idea that getting bored favors development. It was such a key moment.

The growing scientific literacy of citizens, promoted by multiple initiatives, such as the inclusive communication of science from the Spanish Ministry of Science (Flecha et al., 2022), makes it easier for teachers and families to identify the errors like the one involved in this neyroedumyth. Along these lines, another informant said that, in the debate of a public lecture, it was raised that a twitter account with more than 142,000 followers posted on August 14th, 2020, a tweet stating that neuroscience is clear, and getting bored is good for the mind. Our informant shared that such tweet, which did not cite any scientific source of neuroscience, included an article in which such a statement could not be found.

Neuroedumyth 2: Violence Resides in Masculine Genes

Participants in public lectures debates also concluded that a second highly spread neuroedumyth was the idea that violence is constitutive of masculine genes. Some informants shared that one more conclusion from the debates of some public lectures on neuroscience and education was the instruction given to teachers to teach teenage girls that male violence resides in males' genes, and to teach teenage boys how to control their instincts. Our informants added that the trainers giving the audience such an indication related it with the idea that we cannot change what we are. Alba shared along these lines:

> That was one of the most shocking messages that I took from a talk. Supporting the idea that violent behavior is constitutive of males, innate. And what is more, telling girls to accept it.

These research participants also shared two concerns about conclusions from those debates of the lectures given by those who spread this neuroedumyth: first, such neuroedumyth justifies violent relationships among peers in schools, including gender-based violence and child sexual abuse, and second, it places all boys under the category of aggressors, when that is not the case of what they see in their classrooms and school communities. In the words of Victoria:

> That claim that violent behavior is a males' genetic question, justifies all types of violence against girls in schools. Also, it presents all male students as potential aggressors, when there are children and male adolescents who have never attacked a girl and will never do so, but will protect them.

Additionally, some of our informants, who are teachers today and participate in dialogic pedagogic gatherings where they read the most important books on neuroscience and education, such as Kandel's (2007) "In search of memory", shared that they brought to such gatherings those conclusions from those public lectures' debates. In those gatherings, the participants discussed that such a deterministic idea that violence resides in masculine genes and that what we are cannot be changed was contrary to the scientific evidence they had come to know via the reading and discussion of Kandel's works. Laura reported in this regard:

> We all commented on that Kandel's statement about the genes being servants of the environment, which contradicts that hoax.

Neuroedumyth 3: Brain Develops almost Completely the First Three Years of Life

The analysis of the conclusions from the public lectures' debates attended by the informants pointed to a third neuroedumyth: that brain development is almost completed by the third year of life. Our participants reported trainers explaining to them that memory, language and self-regulation are developed almost completely in those first three years. They also shared that a conclusion of those public lectures' debates was that children who have not developed certain abilities between 0 and 3 years of age, would have serious learning difficulties and delays, which would cause these children's school failure. Pere shared along these lines:

> The lesson was clear: all is pretty much decided the first three years, afterwards, any try will hardly succeed.

Our informants expressed their concern resulting from the debates of the public lectures attended where such neuroedumyth was taught. It was the concern with the consequences of such a deterministic view on the development of children, especially for students with disabilities, with immigrant backgrounds or those who live in poverty and have less learning opportunities in their earliest years. One of our informants, who is principal of one school, shared also that in the debate of those public lectures it was clear that teachers who implement Successful Educational Actions and participate in dialogic pedagogical gatherings have managed to avoid the misleading insights coming from that neuroedumyth. This other informant, Paula, shared:

> I was in one of those debates and a person in the audience mentioned an interview to a Spanish neuroscientist who made the statement containing such neuroedumyth. But there was another teacher in the audience, also from a school applying Successful Educational Actions, like mine, who responded sharing evidence from one of her students with disabilities, who via interactive groups and dialogic

> literary gatherings, where enjoyed very rich peer interactions and interactions with diverse adults, had learned to read and developed relevant literacy abilities.

Importantly, this was also a conclusion of such a public lecture debate, the idea that even in very difficult cases, much can be gained thanks to providing children with best interventions.

Neuroedumyth 4: There Are Right-Hemisphere Students and Left-Hemisphere Students

A fourth neuroedumyth that we could identify from the conclusions of public lectures' debates was the one consisting in explaining that there are students who are more prone to use the right brain hemisphere, and other students who are more prone to use the left hemisphere. Our findings show that the conclusions of public lectures' debates by some trainers was that it must be expected that some students are good in academic tasks, those who tend to use more the left hemisphere of their brains, and some students will be good at doing arts and being creative, these will be children and youth who tend to use more the right side of their brains. As Javier explains, it was also concluded in those public lectures' debates that such an idea was related to Gardner's (1983) theory of multiple intelligences:

> I remember very well the explanation that some students being right sided, and others being left sided was also involved in Gardner's theory on multiple intelligences. However, the trainer gave no evidence to show that.

Our informants also showed high concern about the implications of such neuroedumyth: promoting a "curriculum of happiness, emotions and arts" for low achievers (students with disabilities and students from ethnic and cultural minorities, and from low SES), and a "curriculum of competence, of high academic standards" for high achievers. Our research participants shared that this practical implication was often brought by the trainers, more or less explicitly, in their talks, relating it to the "attention to diversity" principle and to the idea that not everyone has to be good at everything. In Alberto's words:

> That there are students better doing with their right hemisphere, and others who do better with their left hemisphere was not neutral in terms of social inequalities. For those good at their left hemisphere was assumed to need an excellent academic curriculum, and for those good at their right hemisphere it was necessary to emphasize the arts and sociability. Thus, they [the trainers] were using such explanation to support the adaptation of the curriculum along the line of Ausubel's theory.

This is another key conclusion of some of those public lectures' debates.

Discussion

Evidence 1: To Develop, the Brain Needs: a) High-Level Stimulation and b) Training

Scientific evidence from the field of neuroscience dismantles the first neuroedumyth reported, that is, the idea that "The brain needs to be bored to develop". This statement contradicts several findings in neuroscience (Kandel et al., 2013). We focus here on two central features of how the brain works: (1) the human brain requires stimulation to develop and, the more sophisticated the stimulation, the greater the development; and (2) training, repetition, and work are the key variables for information to move from short-term memory to long-term memory, that is, for more effective learning to occur.

As for the first feature, stimulation, evidence from neuroscience is clear and strong. The father of modern neuroscience, Santiago Ramón y Cajal, already stated in his autobiography: "The forest of dormant brain neurons must be shaken vigorously; it is necessary to make them vibrate with the emotion of the new and infuse them with noble and high concerns." (Ramón y Cajal, 1917). Here, the Nobel laureate, states it clearly: dormant brain neurons need to not only awaken, but make them vibrate, and which generates such neural activity is new, noble and elevated stimuli. Being bored is opposite to this. In recent years, available technology in neuroscience research has made it possible to evidence this. For example, studies employing neuroimaging have shown that reading Shakespeare's works produces a "tempest in the brain" (Keidel et al., 2013), along the lines of what

Ramón y Cajal said when referring to "vigorously shaking" neurons. Obviously, this is not because of the author of the book being Shakespeare but because the language employed in those pages is more complex and sophisticated. The aforementioned study refers to functional shifts, a rhetorical device much employed by Shakespeare, as producing more complex neural activity.

In relation to the second feature of brain functioning and which dismantles the first neuroedumyth is that training, repetition, and work are key variables for information to move from short-term memory to long-term memory. It is not boredom that leads information to move from very short-term storage to a long-term one, but training, work and repetition. Eric Kandel, the most well-known neuroscientist at present, and Nobel Prize laureate, states in "In search of memory" (Kandel, 2007, p. 244):

> One of the fundamental characteristics of memory is that it is constituted in stages. Short-term memory lasts a few minutes, while long-term memory may last many days or even longer. Behavioral experiments suggest that there is a gradual transformation of short-term memory into long-term memory and that, moreover, this transformation is achieved by repetition. Practice makes perfection.

Therefore, based on what Kandel states in the ground of scientific research in neuroscience, in order to encourage new information of different nature (conceptual, attitudinal, affective) to move from short-term memory to long-term memory and, therefore, to last for days, months and years, children need to repeat the knowledge they have acquired, to practice it. So schools should offer the maximum spaces where girls and boys can train new learning, practice it and repeat it. In this way, everyone can reach perfection in knowledge and skills.

This knowledge from studies in neuroscience of memory, come to reiterate another cornerstone of neuroscience: the use-dependency hypothesis (Kandel et al., 2013). This hypothesis, which refers to the nature of the human brain, indicates that the brain develops according to its use. The more you use your brain, the more it develops; the more you use particular neural networks, the more such networks become stronger and, in turn, the deeper the neural imprint. Again, Ramon y Cajal knew this well from his own

life. In "Recollections of my life" (Ramon y Cajal, 1917), the founder of modern neuroscience stated that:

> The winter evenings went by without missing theaters and gatherings, anxiously peering into the eyepiece. I remember that once I spent twenty hours at the microscope, watching the gestures of a morose leukocyte in its laborious struggles to get out of a blood capillary.

Important advancements in science, like any important learnings for humanity, have involved time, dedication, effort and practice. Contemporary research on human memory and child development (Hedrick et al., 2009) has reiterated these findings, including what types of "practice" and "repetition" provide more effective transition of knowledge to long-term memory. This research has pointed to dialogic interactions (Valls & Kyriakides, 2013; García López et al., 2021) as the most effective.

Evidence 2: Genes Are Servants of the Environment

Eric Kandel, the Nobel Laurate in Physiology or Medicine in 2000, states in his seminal works (2007) that "we are what we are because of what we learn and what we remember" (p. 28). This evidence-based idea contradicts the second neuroedumyth reported in the prior section. In our observations, the teachers shared to be trained into the idea that "what we are cannot be changed". Neuroscience has now accumulated very solid evidence on the non-deterministic nature of the human brain, and of human development more generally, with evidence even applied to gene expression. Again, Kandel states:

> Thus, even though I had long been taught that the genes of the brain are the governors of behavior, the absolute masters of our fate, our work showed that, in the brain as in bacteria, genes also are servants of the environment. They are guided by events in the outside world (Kandel, 2007, p. 310).

On the grounds of this evidence, the idea of violence being constitutive of human nature, and more particularly, of males' biology, is not backed by science. Kandel's publications on the biology of mental disorders (Kandel,

2019) provide one more layer of evidence related to the importance of social experience in gene expression. For instance, when revising research findings on the biology of schizophrenia, the neuroscientist states two points. First, that this severe mental disorder has a powerful genetic component, with independence of the environment and, second, that genes involved in schizophrenia do not act in isolation because the risk to develop the illness only by having the implied genes is not of 100%. in Kandel's words: "genes and environment must interact in order to cause the disorder" (Kandel, 2019, p. 108).

Such neuroedumyth relating violence to males because of being males ignores that socialization plays a key role in developing aggressive attitudes and behaviors in any human being, not only in men. Much research in social sciences has come to provide answers to neuroscience claims that social stimuli and social experience are central in brain development, advancing how social experience shapes the brain. For instance, numerous research studies in sociology, psychology, socioneuroscience, gender studies, etc., have pointed to a dominant coercive discourse, which associates males with aggressive atittudes and behaviors with sexual attractiveness, as one cause for gender violence victimization (López de Aguileta et al., 2021). Children and adolescents are socialized into this discourse via exposure to media and social interactions, where such association is much present. As a result, the coercive discourse that they learn is translated into neural networks in their brains. Therefore, any preference for males with such aggressive attitudes and behaviors is the result of socialization and social coercion (Puigvert, Gelsthorpe et al., 2019).

All this knowledge illustrates the central hypothesis of neuroscience first formulated by Santiago Ramon y Cajal: the hypothesis of brain plasticity. Ramon y Cajal explained this property of the brain as the ability of synapses, neurons and entire brain regions to change their properties in response to use or to different profiles of stimuli (Kandel et al., 2013). Therefore, instead of teaching teenage girls that male violence is in males' genes, and teaching teenage boys the control of their instincts, as some trainers indicate teachers to do with their students, schools should implement the successful actions that have reduced and even erradicated abusive relationships in many contexts, such as the Zero Violence Braves Club (Roca-Campos et al., 2021) and the Dialogic Feminist Gatherings (Salceda et al., 2020). Such successful actions evidence that a safe interactive environment, free from violence, and

where what is attractive is equality, changes preferences and behaviors. That illustrates brain plasticy.

Additionally, knowledge on brain anatomy shows that more than 75% of the brain is neocortex, which is involved in higher order thinking, planning, decision-making, etc. In other words, what is characteristic of humans is not being driven by impulses but regulating those impulses from what makes us truly humans: consciousness (Kandel et al., 2013). From this evidence derives that instead of teaching girls and boys to accept any violent behavior, they should regulate their emotions using the biggest part of their brain on the basis of the people they want to be and the society we dream of.

Evidence 3: There Is Neurogenesis in the Human Brain until very Advanced Age

Neuroscience overcame old ideas from psychology about the restrictive power of sensitive periods in development, which had mainly pointed out that brain development occurs almost entirely in the first three years of life. In Principles of Neural Science (Kandel et al., 2013), after an in-depth review of research on how experience refines patterns of synaptic connections, Kandel states: "we will consider recent evidence that critical periods may be less restrictive than once thought; in some cases they can be extended or "reopened" (p. 1260). What evidence in neuroscience informs is that, precisely due to brain plasticity, a person can develop new neural connections throughout life if engaged with the appropriate stimuli. Therefore, memory, language and self-regulation can be improved at any stage of a person's life if this person has the opportunity, i.e., the stimuli, to engage in learning processes that produce that improvement. For the case of memory, recent evidence strengthens this. In 2019, an article published in *Nature medicine* (Moreno-Jiménez et al., 2019), reported that adult hippocampal neurogenesis is abundant in neurologically healthy subjects. The study showed that new neurons are born in the hippocampus brain of healthy adults up to the ninth decade of life. The hippocampus is the star subcortical structure involved in memory. If there is neurogenesis in the hippocampus of a person who is in her 90's, this means that memory can be trained and can develop beyond the first years of life. Again, as Rita Levi Montalcini (Abbot, 2009) puts it, what matters is what you do with all those neural possibilities, and she is clear about it: "keep your brain excited, active, make it work and it will never get

old". This connects with the already revised hypotheses of brain plasticity and use-dependency, and Levi-Montalcini (2011) herself developed this knowledge in relation to adulthood and old age.

On the grounds of all this neuroscientific evidence, the deterministic idea that the brain develops almost completely in the first three years of life is not backed by science (Bruer, 1999). Any person can improve language, memory and self-regulation at any time in her or his life if, again, exposed to and engaged in the most appropriate stimuli.

Evidence 4: Brain Hemispheres Are not Independent Learning Systems

Studies in neuroscience have already dismantled the idea that individuals can be classified between left-brained, if they are rational and objective, and right-brained, if they are creative and intuitive. For instance, a research by Nielsen et al. (2013) employing functional magnetic resonance imagining (fMRI) data from the brains of more than 1000 subjects, concluded that the results were not consistent with a whole-brain phenotype of greater "left-brained" or greater "right-brained" network strength across individuals. Eric Kandel and colleagues (2013) provide rich data showing that "all cognitive abilities result from the interaction of many processing mechanisms distributed in several regions of the brain" (p.17). Besides, "perception, movement, language, thought, and memory are all made possible by the interlinkage of serial and parallel processing in discrete brain regions, each with specific functions" (Kandel et al., 2013, p.17). What is more, neuroscience research on cortical remapping has evidenced that a person who has suffered from a cranioencephalic traumatism can recover some abilities and behaviors initially lost, because by means of training and practice undamaged parts of the brain reorganize their linkages (Kandel et al., 2013, p.17).

Therefore, supporting the existence of different intelligences and learning styles among students related to the right-brain versus left-brain myth, and the implication of such myth consisting of providing curriculums of different learning levels and social status, does not find any base in neuroscience research. On the contrary, that neuroedumyth has already been tested by neuroscience research (Nielsen et al., 2013) which has concluded that people don't tend to have a stronger left- or right-sided brain network. It seems to be determined more by connection by connection.

Also, in relation to this neuroedumyth to have any relationship with Gardner's theory of multiple intelligences, the same Harvard psychologist has stated in the media that: "Thirty years ago I developed the concept of 'multiple intelligences', and I am pleased to see the interest this idea has found and the way it has been introduced in schools, museums and businesses around the world. However, I am bothered by an unintended consequence. There are many people, including some I hold in high esteem, who have a tendency to give me credit for the concept of 'learning styles' or even conflate it with the term "multiple intelligences". I must set the record straight to alleviate this discomfort (...) Do not use the term "styles". It will only confuse others and does not help you or your students" (Gardner, 2018). Learning styles has been already analyzed as a neuromyth (Yfanti & Doukakis, 2021).

Conclusion

The motivation of teachers for the neuroscientific basis of education opens incredible opportunities for scientific training which may facilitate the improvement of educational results for all (Coch, 2018). International scientific programmes, such as Horizon Europe, make clear the relation between the improvement of results in all areas of human life and scientific evidence of social impact (SESI). The vaccines against COVID-19 in health or the successful educational actions in education are two examples.

The first condition of SESI is to be scientific evidence. Neuromyths are not scientific evidence but, on the contrary, they are hoaxes. They have not demonstrated any improvement in educational results. Neuroedumyths include scientific evidence from neuroscience but develop conclusions for education not based on scientific evidence but on hoaxes about education that have not demonstrated any improvement in educational results

While neuromyths come from teachers' trainers who reproduce hoaxes about neuroscience published by authors who have no knowledge about neuroscience, the most spread neuroedumyths come from teachers' trainers who make statements based on publications of neuroscientists who know very well the brain, but do not know scientific evidence in education. The authors who neither publish neuromyhts nor neuroedumyhts, are those who have rigorous knowledge both about scientific bases of neuroscience and of education.

From the conclusions of the public lectures' debates, it has been clarified that the best neuroscientists only include in their lectures and publications what they know: neuroscience. In their lectures and press audiences, top neuroscientists respond to questions about education saying that they do not know the answer, and frequently teachers feel unsatisfied with the conference and do not grade it high. On the contrary, those researchers in neuroscience who have no success in their own field, look for having success in their lectures and publications for teachers. Because of their orientation to satisfy the audience, to get good evaluations by teachers, and to gain prestige and money, they answer all the questions. In so doing, they give false neuroscientific validity to educational hoaxes, worsening the educational results of children.

The pressure is so strong that even some of those lecturers that criticize this negative process participate in it. For example, there was an interview with one of those neuroscientists in the most popular Spanish newspaper, where the neuroscientist firstly criticized some neuroscientists telling teachers what they should do in the classrooms, but then this neuroscientist replied to educational questions in the interview and published a book on neuroscience and education focused on contributions for the classroom.

New research and publications are needed. We present in this article a reality of creation and dissemination of neuroedumyths which should be overcome. It is now necessary to analyze which interventions, actions, and interactions clarify for teachers and family members which is the scientific evidence of social impact both in neuroscience and in education. In the topic we have analyzed in this article, i.e., neuroedumyhts, the problem is not the teachers, but some teachers' trainers and the publications that introduce neuroedumyths. Teachers and families have great motivation and wonderful capacity for doing what all students need. Now, the task and the duty of researchers is to dialogue with these educational agents about the hoaxes that worsen students' academic and emotional results, as well as about the evidence that makes real the right to best education for all.

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