Global Scientific Production on Neuroeducation: An Analysis in Scopus, 2010 – 2020

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Abstract

The main characteristics of publications on neuroeducation by authors worldwide are described. A descriptive and retrospective analysis of articles 276 indexed in the Scopus database during the period 2010 to 2020 is performed, this database was chosen for having high quality scientific journals. The results indicate that the world scientific production is distributed in 10 documentary types, highlighting the publications of research articles (55.43%), the United States is the country with the highest production, followed by Canada, United Kingdom and Spain. The worldwide scientific production is visible in publications 139, *Mind Brain and Education* (United Kingdom) is the journal with the highest number of publications, followed by *Frontiers In Psychology* (Switzerland). The authors are mainly affiliated to European institutions, being Birkbeck, University of London (United Kingdom), the institution with the highest scientific production, also appears the Jaume I University, Iberoamerican institution with the highest production in this region. Finally, it was found that the most used keywords were the descriptors neuroeducation and neuropedagogy. We conclude that there is still a need for further research on neuroeducation and its implications for educational practice and policy based on knowledge of brain functioning. Even so, scientific production continues to be minimal compared to other psychoeducational variables, so it is necessary to increase international collaboration in research, based on institutions or groups of academics and professionals from different regions.

Key Words: Scientific Production, Neuroeducation, Scopus, Neuroscience.

DOI Number: 10.14704/nq.2022.20.3.NQ22052 **NeuroQuantology 2022; 20(3):126-134**

Introduction

Neuroscience studies the human brain in an interdisciplinary manner. (Lozoya Meza et al., 2018) Its main objective is to study the nervous system by focusing its attention on brain activity and its relationship and impact on human behavior. (Goswami, 2015). Therefore, currently, there is great interest in translating and applying the findings of this field in various disciplines such as law, social policy, economics and education. (Thomas et al., 2019).

Regarding the latter, it is known that the mechanisms of learning and teaching are intimately associated with the functions of the brain (Zadina, 2015). Thus, years of research in this area have led to the formulation of several hypotheses on how people learn, and more importantly, how to apply these findings in educational practice. (Jolles & Jolles, 2021).

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 02 January 2022 **Accepted:** 06 February 2022

Although the academic relationship between these concepts is being actively explored around the world, it is still considered a relatively new and developing area, yet it is recognized as a new and emerging field. (Carvajal, 2021) Nevertheless, it is recognized as a new discipline referred to in a variety of ways and epistemological perspectives: Educational Neuroscience, Neuroeducation, Neuropedagogy or as Mind, Brain and Education. (Carvajal, 2021).

Historically, the concept of neuroeducation originated in the early 1990s, when the "brain-based learning" educational movement emerged, which had the first intentions of associating neuroscience with education. (Salas Silva, 2003). However, the first evidences generated serious controversies, causing topics of debate such as: neuromyths, erroneous beliefs about learning, and misconceptions about education. (Hughes et al., 2020) erroneous beliefs about learning and brain function. (Lithander et al., 2021). However, regardless of its beginnings, neuroeducation has been consolidated as a discipline that combines collective fields corresponding to neurosciences, cognitive science, psychology and education, in order to generate a better understanding of the brain and its function. (Carew & Magsamen, 2010). The aim is to generate a better understanding of the learning process and to use this information to create new teaching methods, curricula and educational policies. (Bruer, 2016)

In the last 15 years, scientifically relevant findings have emerged, for example, evidence to recognize that brain maturation extends at least until the second decade of life of the human being (Martín-Loeches, 2015) This fact has recently been corroborated in studies such as the one carried out by Jolles y Jolles (2021) The brain maturation and neuropsychological development extends throughout adolescence and emerging adulthood, so that in this period there is an important development of the Executive Functions, essential in cognitive learning, social behavior and emotional processing. On the other hand, with the impulse of research based on cognitive neuroimaging, advances were consolidated from memory and learning, to executive functions, emotions, language motor skills (Feiler & Stabio, 2018) and others, such as, for example, the study of sleep and its impact on memory, where evidence has been found to assume that good sleep is not only restorative, but triggers brain changes that help improve memory. (Gilestro et al., 2009).

Despite the development achieved, the relationship between neurosciences and education still does not reach determinant consensuses that allow the integration of findings for the benefit of particular objectives. In this case, the emergence of some criticisms points, for example, to the extrapolation of neuroscientific results from animals to humans, and from laboratories to contexts such as the educational classroom, based on generalization criteria, neglecting the complexity of educational processes (Barrios-Tao, 2016). Despite this, interest in the topic is growing rapidly; thus, for example, the number of articles published using the search terms "neuroscience and education" has increased significantly in the last decades (Feiler & Stabio, 2018)as revealed by a systematic review conducted in Google Scholar, Springerlink and Science Direct, using the keywords: brain-based education, educational neuroscience, brain-based learning and their combinations; finding 176 resulting articles, books and research reports. (Barat Ali et al., 2016).

From what has been reviewed so far, part of the scientific community claims that the empirical evidence generated shows that neuroscience has a sufficient body of knowledge to improve education and can be useful in decision-making at the level of educational policies (Martín-Loeches, 2015). However, in the opinion of other experts, viable solutions that lead to improvements in research and practice have yet to be found. (Pincham et al., 2014) There are worrisome facts such as the lack of knowledge about science and the brain, limitations in accessing relevant scientific knowledge by avoiding neuromyths, and the absence of scientific literature in native languages. (Hughes et al., 2020) and lack of scientific literature in native languages (Torrijos-Muelas et al., 2021).

Faced with this, the authors of the present research see the need to evaluate the scientific activity on neuroeducation in the last decade (2010 - 2020), a period where precisely the greatest scientific advances on the subject have been reported (Feiler & Stabio, 2018; Martín-Loeches, 2015; Zadina, 2015). Therefore, systematizing the knowledge reported in the largest database of citations and abstracts of peer-reviewed literature and high quality sources on the Web, such as Scopus (Cañedo et al., 2010) would fill the gap in knowledge regarding research trends, lines and

interests of researchers worldwide on the academic alliance between neuroscience and education.
Therefore, the objective of this paper is to describe the main characteristics of the publications on neuroeducation by authors from around the world.

Methodology

Study design: Retrospective descriptive study, considered as unit of analysis the publications on Neuroeducation, in journals indexed in Scopus, during the period January 1200 to December 200 and2020 whose authorship mentions affiliations with university and non-university institutions worldwide.
Data collection: Scopus includes more than 40,804 journals in science, technology, social sciences, arts, humanities and medicine, so it was decided to use this database due to the large number of journals included, and its rigorous journal selection process, which allows collecting the most relevant studies on the subject. In addition, Scopus has advantages such as ease of navigation, it includes 100% of what is indexed in the MEDLINE, EMBASE and COMPEDEX databases, and others, facilitating access to cited documents, being open to the Internet, availability of web pages and patents. (Burnham, 2006).
Data analysis: The search included all published and indexed articles, using the fields Article Title, Abstracts, Keywords, using in the search terms the "neuroeducation" OR "neurolearning" OR "neurodidactic" OR "neuropedagogy" OR "educational neuroscience". With the extracted documents, a database was organized in Microsoft Excel that included the following data: name of the signing authors, title of the publication, type of publication, affiliation institutions of the signing authors, journal of publication and country of publication. Finally, with the support of the VOSviewer software, a network was created with the main thematic axes associated with the key words of the publications.

Results

A total of articles 276 published and indexed in Scopus were found. Ten types of publishable documents were included in the analysis. With the highest percentage, %55.43 of documents are research articles (Table 1). During the last years the articles on neuroeducation have been increasing notably with year 2016 containing the highest scientific production on this subject (n=40), and it is from 2015 that publications on neuroeducation exceed 30 articles per year, with the exception of 2017 where the production was lower (n=22) (see figure 1).

Table 1. Documentary type of publications on Neuroeducation

Documentary type	F	%
Research articles	153	55.43
Review	40	14.49
Conference paper	28	10.14
book chapter	26	9.42
note	11	3.99
editorial	9	3.26
book	3	1.09
Letter to the editor	3	1.09
erratum	2	0.72
data paper	1	0.36
Total	276	100.00

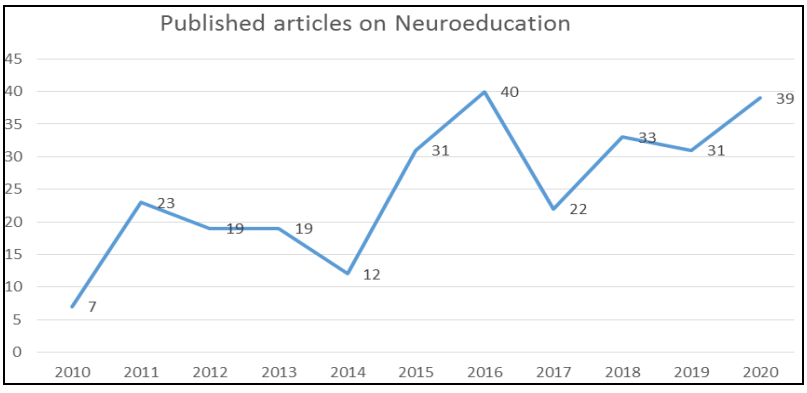

Figure 1. Neuroeducation publications by year, 2010 – 2020

Table 2 shows the countries with the highest production of articles 10 in the period studied. The United States is the country that contributes with the highest scientific production on neuroeducation, representing % 23.55 of the world production, followed by Canada and the United Kingdom, countries that exceed 14,00 % of the production.

Table 2. Countries with scientific production on neuroeducation

Country	N	%
United States	65	23.55
Canada	40	14.49
United Kingdom	39	14.13
Spain	21	7.61
Australia	13	4.71
Germany	12	4.35
Belgium	11	3.99
Greece	11	3.99
Brazil	10	3.62
Netherlands	10	3.62
Other countries	34	12.32

In terms of productivity by institution, 197 international institutions have participated in the production on neuroeducation; the list of the first9 ones is presented, among which the institutions of the United Kingdom and Canada stand out, and %33.33 of these institutions are located within the first institutions11 of the QS World University Rankings 202.0.

Table 3. Institutions involved in Neuroeducation research

Institution	Country	Documents	QS World University Rankings 2020
Birkbeck, University of London	United Kingdom	10	328
The University of Western Ontario	Canada	10	211
Nanyang Technological University	Singapore	8	11
KU Leuven	Belgium	8	80
National Institute of Education	Singapore	7	-
Université du Québec à Montréal	Canada	7	-
Harvard Graduate School of Education	United States	7	3
University of Cambridge	United Kingdom	7	7
Jaume I University	Spain	6	-

Table 4 shows the list of the 10 most productive journals, among which Mind Brain and Education; Frontiers in Psychology and Trends In Neuroscience And Education stand out (journals with articles published greater than 10). Within the thematic areas of these 10 journals, 40% are in the category of Neurosciences. Scientific production is concentrated in journals from the United States, United Kingdom and Germany, which shows that researchers from this region prefer to produce and make their research known in their own environment. In addition, 80% of the journals mentioned are located in quartile 01 and 02, which demonstrates not only the high visibility of the contributions but also their potential quality.

Table 4. Most productive journals on Neuroeducation

Magazines	Country	Quartile	SJR	Category	Documents
Mind Brain and Education	United Kingdom	Q2	0.62	Neurosciences	14
Frontiers in Psychology	Switzerland	Q2	0.95	Psychology	13
Trends in Neuroscience and Education	Germany	Q1	1.04	Neurosciences	11
Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	Germany	Q3	0.25	Computer Science	9
Educational Philosophy and Theory	United Kingdom	Q1	0.45	Social sciences	8
Learning Research and Practice	United States	Q2	0.4	Social sciences	7
Neuroethics	Netherlands	Q2	0.53	Neurosciences	7
ANAE Approche Neuropsychologique Des Apprentissages Chez L Enfant	France	Q4	0.15	Psychology	5
Neuroimage	United States	Q1	3.26	Neurosciences	5
Advances in Experimental Medicine and Biology	United States	Q2	0.53	Medicine	5

Table 5 shows the authors who have contributed the largest number of studies on neuroeducation. Among the authors, researchers such as Daniel Ansari, Stephen R Campbell, Doukakis, Spyridon 145 stand out with the same or more 6 published papers. Within the list of the top 10 authors 50% are subscribed to an institutional affiliation in the United Kingdom and Canada.

Table 5. Authors with the highest production of documents on the subject of Neuroeducation

Author	Institution	H INDEX	documents
Ansari, Daniel	Skånes universitetssjukhus, Lund, Sweden	54	10
Campbell, Stephen R.	Simon Fraser University, Burnaby, Canada	6	6
Doukakis, Spyridon	Ionian Panepistimion, 49100 Corfu, Greece	1	6
Goswami, Usha	University of Cambridge, Cambridge, United Kingdom	59	6
de Smedt, Bert	KU Leuven, 3000 Leuven, Belgium	32	5
Patten, Kathryn E.	Simon Fraser University, Burnaby, Canada	3	5
Fischer, Kurt W.	Harvard University, Cambridge, United States	25	4
Horvath, Jared Cooney	Melbourne Graduate School of Education, Melbourne, Australia	13	4
Masson, Steve	Université du Québec à Montréal, Montréal, Canada	7	4
Thomas, Michael S.C.	Birkbeck, University of London, London, United Kingdom	30	4

With the descriptors 435 selected from a total of those registered 2134 in the 276 retrieved documents, the grouping of five clusters is evident. Red Cluster: Analyzes research on brain development (functional brain) and child development, addressing academic aspects related to working memory and mathematics. Green Cluster: Analyzes the development of educational neuroscience at the pedagogical level, through implementation in the curriculum. Blue Cluster: Analyzes the relationship between neuroeducation and neuroscience teaching in students. Yellow Cluster: Responds to brain studies through neuroimaging in order to diagnose learning problems such as dyscalculia, dyslexia, and others. The purple cluster: Identifies the relationship between procedures and psychological approach in neuroscience (see figure 2).

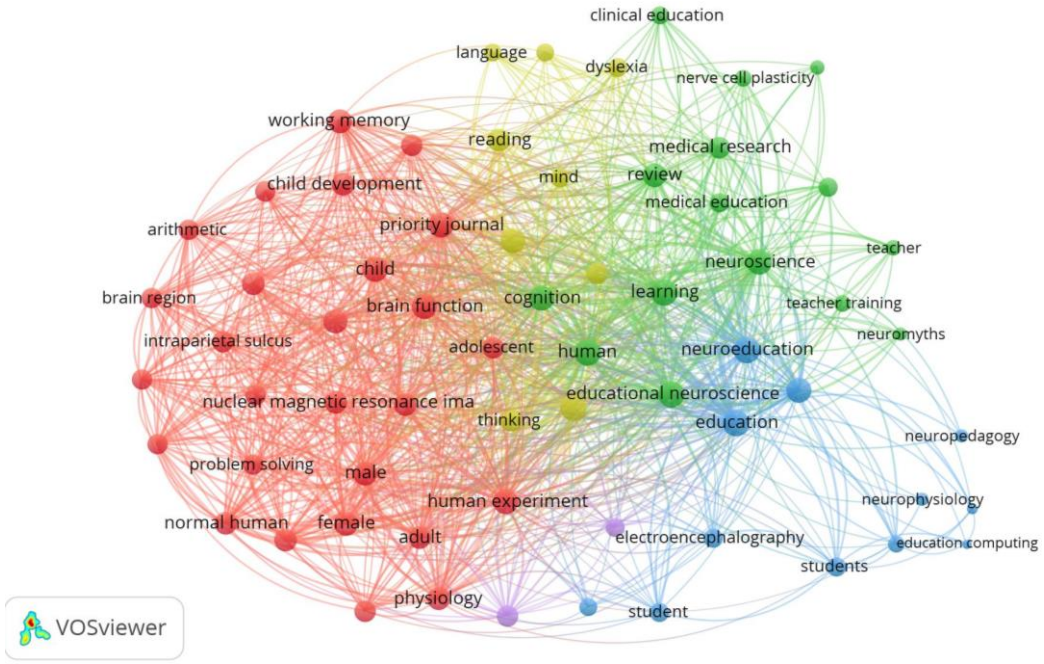

Figure 2. Visualization of a keyword occurrence network

Discussion

The last two years have woven together various misconceptions about the COVID-19 pandemic that have been detrimental to health in millions of people (Lithander et al., 2021). Likewise, various misconceptions about neuroscience and neuroeducation have proliferated giving rise to neuromyths. (Bissessar & Youssef, 2021; Privitera, 2021). Among the causes of the proliferation of neuromyths is that teachers read popular science publications and not refereed journals, which determined the propensity of teachers to believe myths about the brain. (Dekker et al., 2012) Hence, the objective of this research was to describe the main characteristics of publications on neuroeducation by authors worldwide.

The findings show 276 articles found. A considerably small amount if compared to the topic of neuroscience and gender analysis with more than 11590 papers (González-Álvarez & Cervera-Crespo, 2017) or similar to the topic of digital competences with 266 papers. (Rodríguez-García et al., 2019). With respect to the typology of the papers, our results show that 55.43% belong to research articles similar to other areas of study (Hernández et al., 2020) and different to topics related to educational technology, where session papers are the most abundant. (Ferrada et al., 2019).

With respect to the countries with the highest production, the United States, Canada and the United Kingdom are found. This data is similar to other studies that report that it is the more developed countries that publish more compared to developing countries (Wang et al., 2021). It is also important to note that the United States, Canada and the United Kingdom offer postgraduate courses in educational neuroscience, which would also explain this leadership in the field of neuroscience. (Carvajal, 2021; Fischer et al., 2007; Thomas et al., 2019). It is important to note that the first neuroscience society was founded in the United States in the 1970s, which would explain part of the results of the first neuroscience society in the United States in the 1970s. (Lozoya Meza et al., 2018) which would partly explain the results found.

Of the 197 institutions, universities in the United Kingdom and Canada are reported. Interestingly, due to the characteristics of flexibility and breadth, universities become the ideal environment for neuroscience (Li, 2021). Under the Mind, Brain and Behavior initiative, which was launched in 1993 at Harvard University (USA), more similar neuroscience and education programs have been developed at UK universities such as the University of Cambridge and the University of Oxford, and Birkbeck University of London, for example, develops Masters programs in educational neuroscience and generates funding for numerous neuroscience projects. (Carvajal, 2021) and generates funding for numerous neuroscience projects. (Brookman-Byrne & Commissar, 2019; Thomas et al., 2019). In addition, universities are developing neuroeducational research. (Torrijos-Muelas et al., 2021)reports consider the United Kingdom as the country with more institutions involved in neuroscience research than any other country in the world. (Privitera, 2021).

Among the most productive journals, Mind Brain and Education in the United Kingdom, Frontiers in Psychology in Switzerland and Trends in Neuroscience in Germany stand out. These journals are mentioned in different studies highlighting the effort in contributing to the debate on the intersections of neuroscience, psychology and education (Thomas et al., 2019). Likewise, the journal Mind Brain and Education is the oldest journal associated with this field, and Trends in neuroscience and Education in Germany. (Howard-Jones et al., 2016) and Trends in neuroscience and Education is the top quartile Q1 journal. These journals are premised on the premise that neuroscience can improve education. (Bowers, 2016).

Among the most prolific authors is Daniel Ansari. A number of authors comment on Ansari as an author who describes progress and challenges in educational neuroscience (Mackey, 2019). Ansari's contribution comes in various facets such as the application of neuroscience for children with dyscalculia (Wilcox et al., 2021) or summarizing the progress of educational neuroscience over the last few years, or arguing on how neuroscience can be applied to educational neuroscience for children with dyscalculia. (Jamaludin et al., 2019)or arguing how neuroscience can be useful for education by providing parameters or constraints to psychological theories. (Thomas et al., 2019).

The findings in relation to the descriptors found 5 clusters or thematic referents. The first one highlights research on brain development, child development, and aspects related to working memory and mathematics. In relation to mathematics, neuroscience demonstrated the role of non-numerical ordering skills as predictors of mathematical skills. (O'Connor et al., 2019). As well as studies indicating that it is beneficial to teach children to focus their attention on key elements of mathematics and to focus their attention on key elements of mathematics. (Morris et al., 2019). It is also important to mention several studies that identify myths in relation to children's development and aspects related to mathematics. (Bissessar & Youssef, 2021; Privitera, 2021).

A second cluster related to the development of educational neuroscience at the pedagogical level and curriculum implementation. Several studies mention the possible applications of neuroeducation in the face of new curriculum changes (Salas Silva, 2003) and the different curricula (Zadina, 2015). In relation to this topic,

we find the importance of developing a curriculum that helps teachers to select valid sources that can be trusted and avoid falling into myths, as well as the need to develop the ability to use neuroeducation as a tool for the development of the curriculum. (Dekker et al., 2012; Jolles & Jolles, 2021) The need to develop the curriculum of a neuroscientist in university classrooms is also important. (Martín-Loeches, 2015).

The third cluster is related to neuroeducation and the teaching of neuroscience to students. On this topic some authors highlight the role of the use of neuropedagogy as an opportunity to improve and modernize the educational system (Nurmakhanova et al., 2021). The basic premise is that neuroscience can improve classroom teaching through the understanding of various brain changes in response to learning in the classroom, but it still faces an enormous challenge. (Bowers, 2016). However, it still faces an enormous challenge (Schrag, 2011).

The fourth cluster is related to neuroimaging studies to diagnose learning disabilities. Neuroimaging studies can complement behavioral data and improve the understanding of neural mechanisms although without direct application to the field of education (Atteveldt et al., 2020). Some authors emphasize that brain scanning visualized in neuroimaging provides insight into cognitive learning disabilities. (Bravo, 2018). Some experimental studies have been developed with relative success in the application of a neuroimaging program in alleviating learning challenges. (Weber et al., 2019).

The last cluster is related to psychological procedures and approach in neuroscience. Some reports have tried to link neuroscience with education through psychology (Craig et al., 2021; Wilcox et al., 2021). For some years, several authors have been mentioning developmental psychology as one of the areas that can contribute to neuroeducation (Brookman, 2016). They also emphasize that neuroscience is necessary to test the plausibility and validity of psychological theories since psychology ignores the fact that the health of the brain influences all psychological processes simultaneously. (Mackey, 2019; Thomas et al., 2019). Therefore, both neuroscience and psychology must work together and complement each other in order to understand the different educational processes. (Feiler & Stabio, 2018; Howard-Jones et al., 2016).

This research has some limitations. First, although it is a retrospective study, it is likely that some articles were not considered because some journals delay their harvesting process in the databases and it is likely that some articles were not considered. Likewise, the totality of the production in neuroeducation is not presented, since it is only constituted by the Scopus database and not by others such as Web of Science.

Preprints, or early versions of scientific articles, were also not taken into account, and although they offer a rapid dissemination of findings, they increase the risk of disseminating the results. (Torres-Salinas, 2020). However, they increase the risk of disseminating false information, which is perhaps one of the (Casado-Aranda et al., 2021) and perhaps for this reason represents one of the current problems of neuroeducation. It is also important to recognize that there may have been some biases in the filling in of the data, which may have generated some errors.

We concluded that 276 articles on neuroeducation were found between 2010 and 2020 in the Scopus database. The countries leading this production are the United States, United Kingdom and Canada and the journals with the highest production are Mind Brain and Education, Frontiers in Psychology and Trends in Neuroscience and Education. We emphasize that although positive advances were made in the study of neuroeducation, the findings found in this research offer thematic networks and a direction for future lines of research.

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