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Neuroeducation and impact on higher education: a systematic review

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ABSTRACT

The educational system is always seeking to optimize the teaching-learning process through new methodologies. In this sense, there is an effort to improve the student's academic performance through the acquisition of the desired knowledge that will also last in time. Given this reality, neuroeducation is born as a contribution to the development of the educational system within a scientific basis that understands the way people learn. In this context, the objectives were to determine the impact of neuroeducation in higher education and to describe the current state of strategies based on neuroeducation in the higher educational context. Therefore, a systematic review of the literature was carried out applying the PRISMA method, establishing a periodic range of 5 years (2018-2023). The articles selected in this review were 47 documents. The results showed that this discipline has many benefits for students to learn properly, although teachers have little knowledge about it. Finally, it is concluded that neuroeducation brings with it strategies to improve teaching based on stimuli and motivation, thus achieving a good academic performance by the student.

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1. INTRODUCTION

Neuroscience focuses on the study of the nervous system and brain activity, as well as their relationship and impact on human behavior [1]. On this matter, many authors have recognized that knowing in greater detail how the brain works is fundamental to achieve an improvement in the learning process [2]. Therefore, understanding the brain mechanisms responsible for learning and memory, as well as influencing factors such as environment, age, motivation and emotions, is essential to change current educational strategies and optimize learning [3]. A significant finding concerns the plasticity and adaptability of the brain, which was previously considered static and inflexible, and which is now leveraged by teachers to develop neuropathways and interconnections that improve students' academic success [4]. A previous study has already shown that educational interventions based on neuroscience allow better teaching results to be obtained [5].

In this context, a new discipline known as neuroeducation or educational neuroscience emerges, which is based on the contributions of cognitive psychology, educational sciences and neuroscience [6]. Through this approach, it is possible to take advantage of the knowledge about how a human being is able to learn in order to create educational methods capable of generating a more effective teaching-learning process [7]. In this regard, it has been found that the brain has the ability to create new pathways and generate neuronal

development. In turn, the biological factors responsible for this process are governed by genetics, which also influences the learning environment [8]. Regarding this, a study carried out in Ecuador demonstrates that considering cognitive processes in the teaching-learning process allows the personalization of teaching and ensures the success and achievement of the stated objectives [9].

In higher education, the inclusion of programs based on neuroeducation is required, as it allows teachers to focus on specific characteristics of each student [10]. A study conducted at a university in Ecuador showed that programs based on neuroeducation foster the consolidation of knowledge, increase student curiosity and attention, and also allow the design of effective and quality teaching methodologies for future teachers [11]. Another study conducted in Bolivia implemented a video game based on the predominance of the hemispheres of the brain and showed that learning was enriched thanks to the game and the neuroeducation approach [12]. Another study demonstrated the effectiveness of games in affecting neuroscientific aspects related to students' cognitive functions [13].

According to a bibliometric analysis on the subject [14], research on the inclusion of neuroscience in educational settings has increased during the last decade. However, there are still gaps that need to be overcome in order to correctly determine the influence and relationship of neuroeducation with higher education [15]. Based on this, the following research problems were posed: i) What is the impact of neuroeducation in higher education?; and ii) What is the current state of strategies based on neuroeducation in the higher educational context? The objectives were to determine the impact of neuroeducation in higher education and to describe the current state of strategies based on neuroeducation in the higher educational context. For this purpose, a systematic literature review was conducted in five databases and establishing a time limit of five years (2018-2023).

2. LITERATURE REVIEW

2.1. Definition of neuroeducation

Neuroeducation is a discipline that comprises the synergy between neuroscience, psychology and pedagogy, and focuses on understanding the functioning of the brain in its different stages of development and its influence on the learning process. It also studies how the brain learns, controls emotions, interprets and stores information, and reacts to behavioral states and stimuli [6]. In this context, it is based on a concept known as neuroplasticity or brain plasticity, defined as the brain's ability to constantly change in response to environmental stimuli [16]. Importantly, each individual's responses to new information are based on a unique combination of their genetics and environment [4].

From the knowledge acquired through neuroscience, it is known that, at the moment of birth, a child already has almost all the neurons that will be present for the rest of their lives. For this reason, it is important to start stimulating them during their first three years, in order to enhance their ability to absorb knowledge and develop their innate potential, taking advantage of the great neuronal plasticity they have at that age to achieve higher brain levels [17]. In this sense, through brain plasticity, knowledge is acquired, and a network of neuronal connections is gradually established, which are called Hebbian networks. These established connections favor the expansion, strengthening and growth of neural networks, which are the basis of learning [18].

This knowledge regarding the learning process of the brain represents important tools for teachers to innovate learning in their classrooms, making it more effective and meaningful [6]. Therefore, an adequate implementation of neuroeducation requires of teachers who not only have the appropriate training within their field, but also have basic knowledge regarding neuroscience in order to generate a positive impact on educational programs by improving their teaching methods [7]. Currently, it is important to disseminate scientific discoveries in the field of neuroscience, especially to teachers. This is so that they can make use of them in their work, as well as to combat problems such as neuromyths, understood as misconceptions about the mind and the brain [3].

3. METHOD

For the present work, a systematic review of the literature was conducted, using the criteria of the preferred reporting items for systematic reviews and meta-analyses method (PRISMA), which allows to integrate the results of studies systematically and objectively on a specific topic [19]. This search focused on gathering information about the impact of neuroeducation on the teaching-learning process in higher education, as well as teacher preparation in order to be able to implement it in their classrooms and improve student learning. Therefore, we seek to answer the following questions: ii) What is the impact of neuroeducation in higher education?; and ii) What is the current state of strategies based on neuroeducation in the higher educational context?

The information was obtained by reviewing five bibliographic databases: ScienceDirect, Scientific Electronic Library Online (SciELO), Dissemination of Alerts on the Web (Dialnet), EBSCO, and REDIB, since

they cover a large number of scientific articles, both in English and Spanish and from various parts of the world, including Latin America and the Caribbean [20]. To obtain updated information, articles published from 2018 to the present year were considered. Additionally, keywords in Spanish such as "neuroeducación" and "neurociencia educativa", "educación superior" in addition to keywords in English such as "neuroeducation", "educational neuroscience", "higher education", "learning" and "teaching" were used for the search. The keywords were combined using Boolean operators [21], such as "AND" and applying them in sentences such as (neuroeducation) AND learning AND teaching, among others.

After searching for articles with keywords related to the topic of interest, an initial total of 294 articles were obtained. From this first group selected, the bibliographic manager Mendeley allowed us to store these articles, and at the same time eliminate duplicate publications for a total of 272 articles. The inclusion and exclusion criteria indicated in Table 1 were then taken into consideration for the final selection of articles.

Within this second selected group of 74 articles, a more exhaustive review was conducted, analyzing the full text of each one, to finally select 47 articles that were part of this study. The bibliographic manager Mendeley was used to store, organize and analyze the bibliographic references obtained in the search [21]. Figure 1 shows in detail the selection process of the articles at each stage, as a result of applying the PRISMA methodology.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion criteria
Publications referring to neuroeducation in higher education.	Publications on other topics.
Publications since 2018.	Publications before 2018.
Publications in English and Spanish.	Publications in languages other than Spanish and English.
Publications from the following databases: Scielo and ScienceDirect, Dialnet, EBSCO, REDIB.	Publications from other databases.
Quantitative or qualitative research and review publications.	Publications that are not research or review publications.

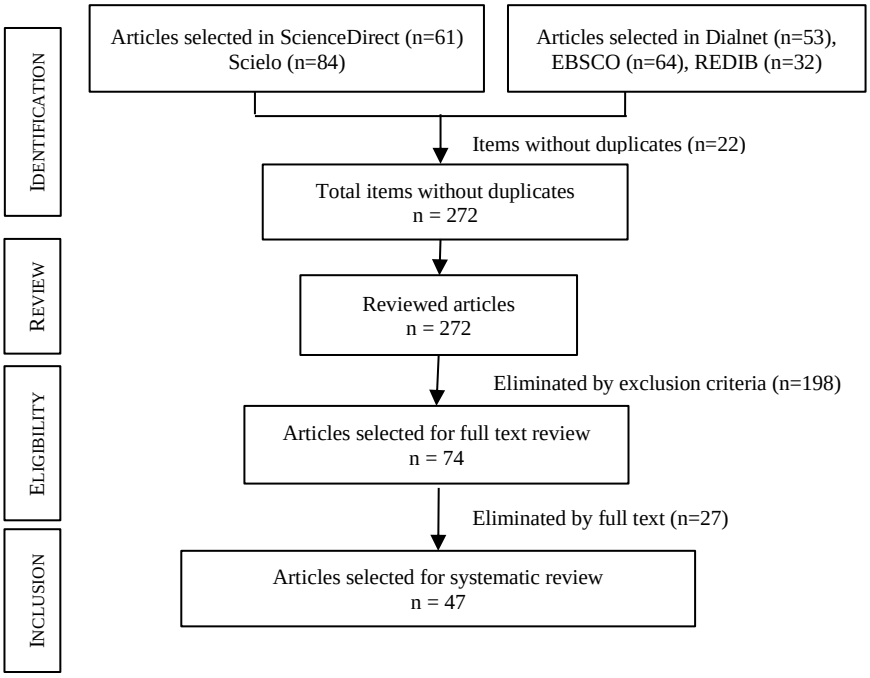

Figure 1. Article selection flowchart PRISMA method

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Characteristics of the selected articles

A total of 47 publications were selected, according to the inclusion and exclusion criteria in Table 1 established for this systematic review. To facilitate the analysis of the information, the most relevant points of each article were registered in an Excel database [19]. From this, it was observed that, within the group of publications, 18 (38.3%) articles were published in English, while the remaining 29 (61.7%) were in Spanish Figure 2.

Figure 2 shows that most of the publications are in Spanish, despite the fact that most of the articles initially selected correspond to the ScienceDirect database. Although neuroeducation is an emerging topic, the number of publications in English has not been very high, showing a preference for this topic in Spanish-speaking regions. In addition, it was determined that 21 articles (44.7%) were review articles, while the remaining 26 (55.3%) were research articles. Figure 3 shows the distribution of publications by each database considered.

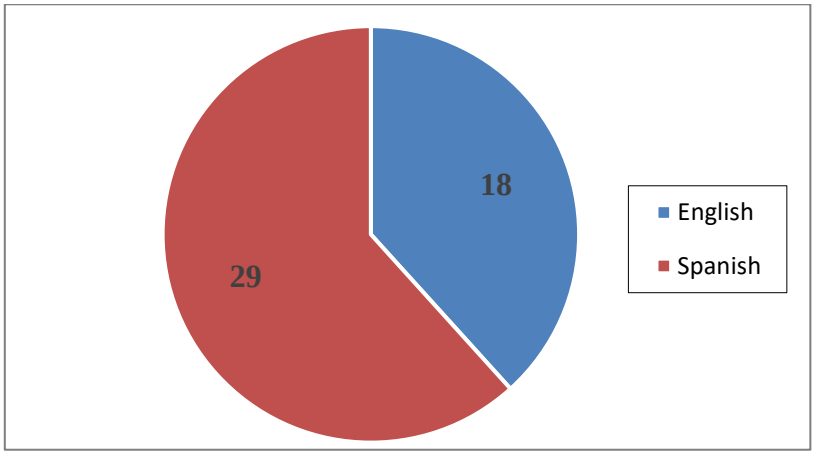

Figure 2. Distribution by language of publication

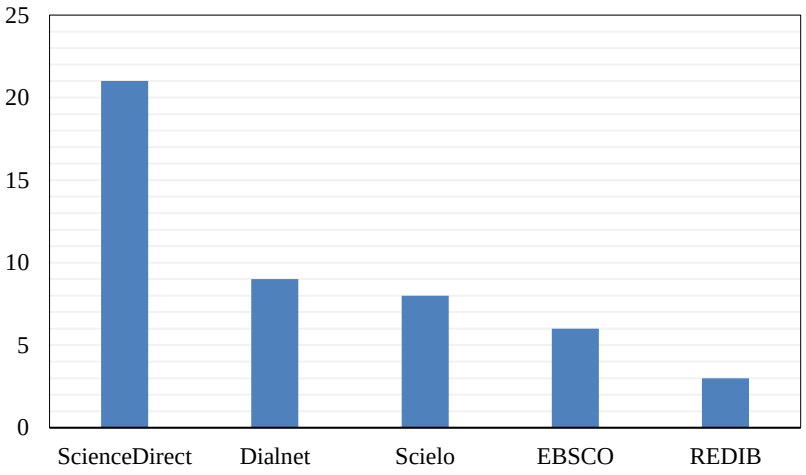

Figure 3. Distribution of articles by database

As presented in Figure 3, it was determined that the largest number of publications compiled corresponded to 21 (44.7%) articles from the ScienceDirect database, followed by Dialnet and Scielo with 9 (19.1%) and 8 (17.0%) articles, respectively, and REDIB was the database with the fewest publications, with a total of 3 (6.4%) articles. In addition, Figure 4 shows the number of articles selected according to their year of publication.

Figure 4 shows that there is an increase in the number of publications for each year. The year 2022 presents the highest number of selected articles with 15 (31.9%) publications. This increasing trend shown in recent years seems to indicate that the subject of neuroeducation is attracting more and more interest from researchers, given the good results obtained in the teaching-learning process. In the present year 2023 only 6 (12.8%) articles were selected, which is due to the fact that it is a current year and there are not yet many publications on the subject. In addition, Figure 5 shows the distribution of the selected publications according to the country where each study was conducted.

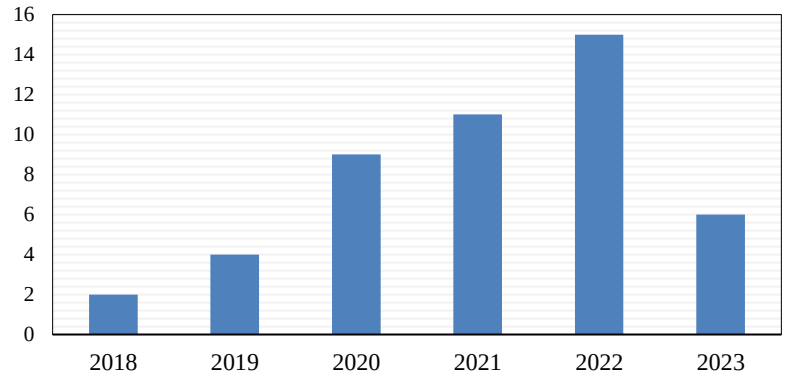

Figure 4. Distribution of articles by year of publication

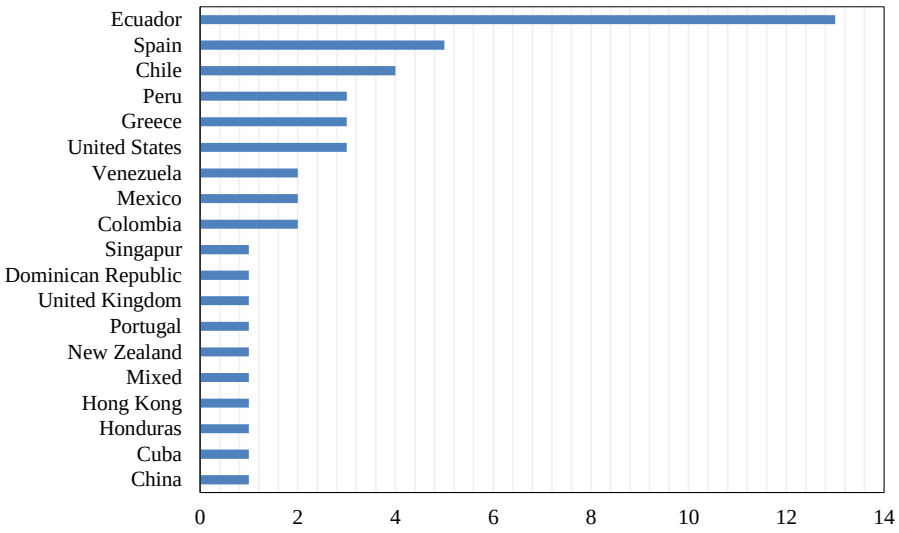

Figure 5. Distribution of articles by country

Figure 5 shows that the selected publications were collected from various parts of the world, including the Americas, Europe and Asia. Among the countries with the highest number of articles selected is Ecuador with 13 (27.7%) articles, followed by Spain, and Chile with 5 (10.6 %) and 4 (8.5 %) articles respectively.

In addition, the content of the publications was analyzed using VOSviewer software. Based on the keywords of the articles in both English and Spanish. For this purpose, a minimum value of 4 occurrences was defined to relate the different keywords. From the result obtained, the words less related to the concept of neuroeducation, the central theme of this work, were discarded. With the most relevant terms, 11 selected for this case, the respective bibliometric network was generated from this information as seen in Figure 6. Of the 47 articles selected, the keyword "neuroeducation" was the most relevant one, present in 20 of them (43.0%).

From Figure 6, it can be seen that the terms have been grouped into three clusters differentiated by colors (in order of importance) green, red and blue, with 3, 6 and 2 terms respectively. The green cluster represents the studies related to neuroeducation and emotions, being "neuroeducation" the term with the highest occurrence and therefore of greater relevance for this work, present in 20 (42.6%) articles, followed by "neuroeducación" and "emotions", present in 15 (31.9%) and 5 (10.6%) articles respectively.

The red cluster represents studies related to neuroscience, on which neuroeducation and higher education are based. It contains the keywords "neuroscience" and "higher education" present in 10 (21.3%) and 8 (17.0%) articles respectively and also includes keywords such as "learning", "teaching" and "neurociencia" present in 5 (10.6%) articles and finally "higher education" present in 4 (8.5%) articles. As for the blue cluster, it contains keywords related to neuroscience where the words "neurociencias" and "neurosciences" are present in 4 (8.5%) articles.

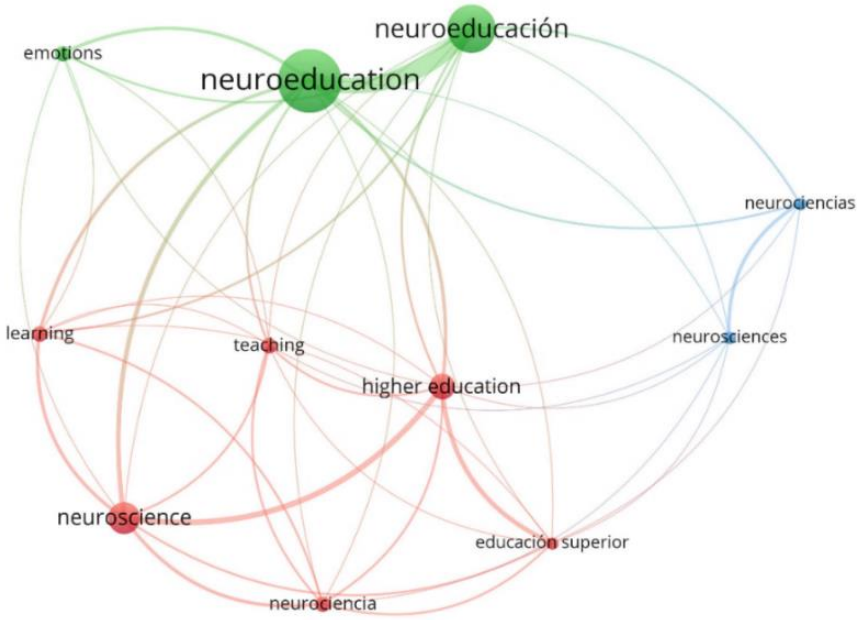

Figure 6. Bibliometric network with keywords of highest occurrence

Additionally, it is observed that among the clusters there are words that correspond to the same concept or that are in Spanish and English. In this sense, "neuroeducation" and "neuroeducación", address the same concept and are present in 20 (42.6%) and 15 (31.9%) articles respectively, and when grouped, it is obtained that they are present in 35 (74.5%) articles in total, confirming that the selection of articles is adequate. Something similar occurs with the keyword's "neuroscience", "neurociencia", "neurociencias" and "neurosciences", which together are present in 23 (48.9%) articles. Additionally, the terms "higher education" and "educación superior" are present in 12 (25.5%) articles.

In general terms, the review publications about neuroeducation in higher education were narrative, systematic, critical, or a case study. These publications sought to explore the tools that neuroeducation provides to enhance the educational experience, and the potential of neuroeducation to generate positive change within higher education. Likewise, they explore this process of implementing new methodologies based on neuroeducation, and at the same time, recommendations and opportunities for improvement are enunciated in order to correctly take advantage of the knowledge provided by neuroscience in the educational field.

On the other hand, the research publications focused on evaluating teachers or students at this educational level to measure the impact of neuroeducation on them. To this end, the studies analyzed use a series of instruments to collect the necessary data according to the aspect of neuroeducation they are studying, which are shown in Table 2, as well as the number of articles that have used them.

Table 2. Instruments or method used in research publications

Instrument	Number of articles	References
Questionnaire	18	[17], [22]–[38]
Interview	2	[39], [40]
Experimental	3	[41]–[43]
Documentary review	2	[44], [45]
Rubric	1	[46]

Through these instruments, the different studies have sought to evaluate neuroeducation in various aspects. Since the knowledge and experience of teachers and students are fundamental for the success of these methodologies, aspects such as teachers' knowledge of neuroscience, students' performance with neuroeducation, the presence of neuromyths in them, educational proposals based on this discipline, among others, were evaluated.

4.1.2. Impact of neuroeducation in higher education

The students have benefited from neuroeducation, since programs based on this discipline are more effective in capturing their attention and giving them a more active role in the classroom. In addition, it provides them with a more inclusive education, which normalizes the expression of feelings within their learning process [47]–[49]. However, these changes require that the traditional model of the teacher be broken, and that these professionals receive adequate training in neuroeducation. From this, it is important to restructure the education of teachers themselves to include topics related to the brain and learning, so that they are able to apply neuroscience and become neuroeducators [50]–[53].

Neuroscience has the potential to improve the comprehension, capacity and understanding of the knowledge acquired by students, avoiding stressful situations that can hinder their exposure to knowledge. As a result, it is possible to positively impact their academic performance and obtain higher quality professionals in the future. Similarly, distance education mediated by this discipline is more attractive and bearable for students in situations such as a pandemic [11], [54]–[57]. From this, a series of improvements to be made involving intervention strategies that apply concepts such as neurodidactics in education are identified. Similarly, tools such as ICT can complement neuroeducation, as long as they are implemented by trained personnel who understand how to apply them to improve the educational experience of their students [58]–[63].

Furthermore, it was found that strategies based on neuroeducation have a positive impact on the satisfaction and academic performance of students. Socioemotional strategies and a positive classroom climate motivate students to learn, something that is reflected in the results obtained in subsequent evaluations [34], [36], [43], [46]. Through leveraging all communicational channels, neuroeducation strengthens student learning by creating distinct and unique perceptions for each student [30], [35]. In this context, to improve the application of neuroeducation it is important to consider the individual differences of each student, in relevant aspects such as academic climate, activities, and assessments, and to continue exploring the pedagogical tools offered by neuroeducation [28], [29], [33], [38], [42], [45].

4.1.3. Current state of neuroeducation in higher education

Currently, the knowledge offered by neuroscience is not being fully applied within the educational system. Despite the empowering strategy that neuroeducation represents, profound changes are still required in this sector to improve the educational experience of young people and transform it into a quality one [64]. In addition, neuromyths are present as a strong problem in both students and teachers, as a consequence of the little scientific literature available or weak scientific communication, a problem that needs to be eradicated from their minds [65].

Likewise, in several countries, neuroeducation is not only not effectively implemented, but teachers have little knowledge about how the brain works. Moreover, their interest in increasing their knowledge in this field is notorious, although very few teacher training programs have a neuroeducation approach [17], [31], [32], [37], [44]. On the other hand, the high prevalence rates of neuromyths in teachers and students are alarming, with a rate of 99% in some cases, a situation that is particularly observed in Latin American countries and represents an important problem to be addressed [24]–[26].

4.2. Discussion

The first objective was to identify the impact of neuroeducation in higher education. The results show that the incorporation of neuroeducation was effective in capturing students' attention and giving them a more active role in the classroom. These results coincide with those obtained by Jarquin [66], who stated that a strategy that considers the neural aspects of students and their way of relating to others enables collaboration and student involvement. Other studies have shown that the best way to capture students' attention is through strategies such as the flipped classroom. A study by Campos [67], conducted in Mexico, showed that the inverted classroom increased students' interest in the subject, improved the quality of their learning, the perception of their workload and satisfaction with the subject. For its part, a study conducted in Peru showed that the inverted classroom improves the cognitive learning of higher education students, encourages participation and increases interest in the subjects [68].

It was also demonstrated that strategies based on neuroeducation allow, in university classrooms, the teaching-learning process to be inclusive. However, a study conducted in Spain showed that the relationship between neuroeducation and inclusion is low, so it recommends strategies that focus on addressing the diversity of students to achieve true inclusion in the classroom [69]. A study showed that inclusion in the classroom is achieved through a consolidated educational strategy that allows a broad level of personal and cognitive development in which students and teachers are immersed, while recognizing the subject's own capabilities and possibilities [70]. In another study conducted in Ecuador, it was stated that the first step for inclusion in higher education is the enactment of initiatives by institutions and the commitment of teachers [71].

Neuroscience has the potential to improve the understanding of knowledge acquired by students, avoiding stressful situations that may hinder their exposure to knowledge. This is consistent with the results of

Perabá and López [72], who demonstrated that neurodidactics reduces student and teacher stress, since neuroscience-based strategies allow identifying the needs of each student individually and reduce the workload. Likewise, Suira [73] demonstrated that didactic strategies that encourage social skills, emotional self-awareness, empathy, adaptability and self-regulation of emotions allow reducing the stress manifested by teachers and students. On the other hand, deficient didactic strategies have negative effects on the stress of university students, since a study showed that stress levels increase when teachers are unable to respond to the needs of students [74].

Another significant finding is related to academic performance. The analysis of the selected publications allowed demonstrating that strategies based on neuroeducation allow improving the academic performance of higher education students. These results coincide with those of another literature review, which showed that strategies based on neuroeducation improved academic performance, compared to traditional teaching, specifically methodological and socioemotional ones, through interactive tactics and play that allow the generation of positive emotions [75]. Another literature review showed that neuroeducation favors the training of higher education students and significantly influences academic performance [76]. Finally, in a study conducted in Venezuela, it was shown that strategies based on neuroeducation improved academic performance, as 90% of students obtained passing grades, compared to 40% who were exposed to traditional strategies [77].

The second objective was to identify the current state of neuroeducation-based strategies in higher education. The results have shown that profound changes are still required in higher education to improve the experience and quality of teaching. This reality is of increasing concern, as teachers lack knowledge of neuroscience, making it difficult to incorporate neuroeducation-based strategies. And progress in neuroeducation may be hindered, and that authors have been skeptical about the relevance of neuroscience for education, claiming that evidence from psychological experiments examining behavior suffices for education [78] and advocating a social approach to conflict resolution, rejecting neural and psychological aspects [79]. However, other studies affirm the need to understand teachers at the social and psychological level [80], so the fundamental role that neuroscience can play in higher education should not be dismissed.

In educational practice, teachers should have the ability to choose the most appropriate type of learning according to the characteristics of the students in their charge, such as motivation, previous knowledge, skills, among others, in order to provide better training to students. future professionals. To this end, it is recommended to incorporate neuroeducation in the formative stage of teachers, since, as stated by García-Valdecasas *et al.* [59], it is necessary for teachers to have knowledge about neuroscience and technology; neurodidactics and technological aspects and neuroeducation programs to provide a quality educational experience. On the other hand, within the classroom, tests should be applied to groups of students to check in detail the results obtained on knowledge retention, decision making and problem solving [81]. Finally, in the classroom, interaction with other students, concept analysis, problem posing, content application, and the promotion of systemic thinking should be promoted in order to provide a didactic experience based on neuroscience [82].

5. CONCLUSION

As a result of the systematic review conducted, the advantages provided by the application of neuroeducation in the teaching-learning process in higher education students have become evident, by allowing a more active participation of them. With the application of neuroeducation in the educational system, there is a teaching-learning process with scientific support, as opposed to the traditional one. In this sense, the findings obtained from neuroscience studies focused on the development and functioning of the brain during the teaching process have the potential to change the traditional educational approach to one centered on emotion and motivation as key elements for acquiring significant knowledge that lasts over time.

On the other hand, neuroeducation continues to be an emerging science that has not yet been widely spread within the educational system and, therefore, its potential is largely wasted. In this context, it is essential to continue with teacher training programs, and even include neuroscience topics throughout their formative period, so that they can become familiar with these concepts from an early stage and explore the benefits they offer in the academic environment. In other words, teachers should be adequately trained and motivated to apply in their classrooms all the strategies that neuroeducation offers. In this context, a teacher with solid knowledge in neuroeducation will be able to help students learn the most difficult courses within each university career.

Given the benefits that neuroeducation has shown so far, this discipline is arousing greater interest among educators in recent years. From this, it is possible to select the teaching methodology that offers the best results, in order to find one that best suits the type of students in their charge, and that these can achieve the desired learning. In addition, it is highlighted that, through the application of neuroeducation, inclusive

teaching is offered. Given that the brain is unique to each student, it is important to consider the great diversity of learning abilities that students possess. In this sense, the teacher has in his hands a great responsibility to take advantage of the benefits provided by this new science and change the traditional educational process into a more effective one with greater academic benefits for the student.

This review was carried out in different databases: Scopus, Dialnet, REDIB, Scielo and EBSCO, but given that the inclusion criteria considered research in Spanish, the research belonged mainly to Latin American countries. Another limitation was the publication period addressed, since we sought to obtain the most current results, we opted for the period 2018-2023. Future research should extend this period and cover, for example, a decade of studies, as well as be carried out in other databases or specifically in one. This will make it possible to show the evolution of neuroeducation in higher education and the change in the appreciation of this discipline. Finally, neurodidactic strategies can be implemented in all types of education, other reviews can be conducted in primary or secondary education, as well as a comparative study to demonstrate the effectiveness of these strategies at different educational levels.

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