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Review Article

Contributions of Neuroscience to Educational Praxis: A Systematic Review

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Abstract

Objectives: In education, neuroscience is an interdisciplinary research field. It seeks to improve educational practice by applying brain research findings. Additional findings from the scientific fields of education, psychology, and neurophysiology aim to enhance the learning process and improve educational practices. The application of neuroscience to education involves neuroscientific and psychological knowledge. *Methods/Analysis*: In this systematic literature review, the final studies included in the analysis table are decided by searching databases according to predefined inclusion criteria. The PRISMA approach was utilized to study the relationship between neuroscience and the educational process and to optimize the educational process based on the relevant data. *Findings*: The review's findings emphasize the significance of integrating neuroscience into educational praxis and challenges and raise ethical concerns regarding its implementation in educational contexts. *Novelty /Improvement*: The discipline of educational neuroscience is associated with education, research, and the cognitive neuroscience of learning. Neuroscience can serve as the basis for education in a similar direction that biology serves as the basis for medicine, meaning that each field retains its innovation but cannot contravene the rules of the other. This study examines the relationship between neuroscience and educational praxis as well as how the educational community might bridge this gap to include prospective findings from neuroscientific research.

Keywords:

Educational Neuroscience;
Neuroeducation;
Pedagogy;
Cognitive Psychology;
Education.

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1- Introduction

Educational neuroscience is an interdisciplinary branch of study that aims to incorporate insights regarding neural learning mechanisms into educational practice and policy. Based on studies on behavioral regulation, decision-making, reward, empathy, and the moral agent, there are comparable domains that seek to apply neuroscience results to law, economics, and social policy [1]. This discipline is also a fundamental science that investigates how education affects the brain and what mechanisms lead to behavior modification because of education. In addition, several academics are interested in the relationship between neuroscience and educational leadership, citing the term neuroleadership [2] as they seek a framework to support leadership and organizational performance in educational contexts. In addition, the study of neuroscience and its impact on human behavioral response systems requires educational leaders to investigate human dynamics and the definition of an organization's culture, mission, and role [3–5]. In addition, educational leaders (teachers, professors, principals, and academic teachers) can use brain research to tap into other people's cognitive functions by achieving more effective and constructive communication for optimal interpersonal collaboration, which constitutes a high degree of social, emotional, and cultural intelligence [6].

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Educational neuroscience, also known as neuroeducation, is a rapidly expanding interdisciplinary field that studies and integrates results, theoretical frameworks, and approaches from the pedagogical and cognitive sciences, brain sciences, psychology, and other disciplines. Neuroscience and education are primarily intertwined and interact with the ultimate purpose of enhancing learning and teaching. Neuroscience is becoming increasingly focused on the relationship between the brain and learning nowadays [3]. Neuroplasticity is a vital bridging process, and its molecular, neural, and cerebral processes should be studied in greater detail in the future. In addition, the methodologies of neuroscience and cognitive science have progressed to the point where we can now accurately follow the developmental trajectory of a child's brain and document how this trajectory is influenced by parenthood, learning, and other external factors.

Educational neuroscience research leads to the identification and development of ways that both educators and students can employ to enhance the learning experience and to a better understanding of how individuals acquire [4]. Specifically, it improves the training of teachers by providing them with information about the brain, enabling them to build more appropriate learning environments for their learners and employ more successful teaching approaches. In addition, neuroeducation facilitates the development of mechanisms that enable learners to successfully adapt their behavior to the demands of their social and cultural environment [5]. In the end, the objective of education is the individual's holistic growth, and in particular the mastery of the three basic abilities, namely literacy, mathematics, and social, emotional, and moral skills, which are seen as essential for the development of the whole.

2- Literature Review

2-1- Educational Neuroscience

Throughout the 20th century, neurobiology's importance to education was acknowledged [7]. Not until 1990, during the so-called "*Decade of the Brain*" [8], did technical advancement play a significant role in in vivo brain imaging. This discovery led to the theoretical advancements that made educational neuroscience possible [9]. Despite substantial criticism [10] and significant ongoing debate [11] concerning the advantages of knowledge from neuroscientific research on educational challenges, potential linkages between neuroscience and education are being researched throughout the world. The description utilized various methodologies, including Neuroeducation, Educational Neuroscience, and the brain in education. There is a demand for brain-related education in schools.

Educators want their students to receive the benefits of the "neuroscience century." Significant progress is being made in neuroscience laboratories to comprehend the neurocognitive development that underlies the acquisition of essential skills taught by educators, such as numeracy and literacy. This development is primarily theoretical. The relationship between neuroscience and education is enhanced by brain-science-based packages and programs. It is astounding how quickly these programs have acquired popularity in classrooms. It may be more advantageous for society if neuroscientists build and support a network of communicators who can bridge the gap between neuroscience and education by disseminating high-quality information in an easily digestible style. These communicators and researchers could act similarly to the information officers of medical organizations, but in this instance, they would explain the most significant discoveries in neuroscience to elementary school students. These individuals are scientists with an interest in education, possibly affiliated with universities or national education departments. They interpret neuroscience via the lens of teachers' language and analyze teachers' research questions and proposals for neuroscientists [12]. There must be collaboration between neuroscientists and educators in order to bridge the gap and provide considerable benefits for classroom students. Children with learning impairments, for whom considerable brain and neuroscience research has been conducted, will benefit the most.

Educational neuroscience is a combination of various disciplines. It employs techniques from a variety of scientific disciplines to transform results from the study of the brain and its neural networks into useful educational outcomes [13]. Neuroscience in educational or academic settings The field of neuroscience has shed light on a specific facet of the learning process. Learning that begins in the earliest stages of human life and is cultivated more intensively in the school environment is dependent on the developmental functions of the brain, the psychological framework, the environment of lifelong learning, the cognitive functions, as well as the emotions and motivations that are cultivated as a means to its conquest. Regarding Howard-Jones and his peers [13], "Educational neuroscience is much more than a method for enhancing, explaining, or analyzing teaching". It then uses these findings in the classroom [13]. According to Wilcox et al. [14], "educators and school psychologists possess the bilingual skills necessary to comprehend both basic neuroscience and education, let alone the psychological constructs associated with both disciplines". For this reason, their involvement is deemed essential.

The objective of many national education and training systems is learning. The application of the educational process in the classroom facilitates learning through the use of standard cognitive functions. Enhancing performance, cognitive mechanisms such as working memory, long-term memory, and attention [15] contribute to the learning process. In addition, high brain activity is connected with attentional focus. In one of the experiments recorded by scientists [16] using the neuroimaging technique and specifically functional magnetic resonance imaging (fMRI), "they determined how these shifts of attention affect brain activity by asking an observer to covertly shift their attention to various regions of an image. As attention shifted from one location to another, the experiment revealed that "the increase in brain activity migrated away from the center." Therefore, attention increases activity in the regions of the brain's topographic map that correspond to the focus of the participant's attention. Researchers [17] discovered that "mathematics and science-related tasks frequently require students to visually or cognitively separate the pieces from the whole." This is how the brain directs a person's attention and enhances other cognitive skills, such as working memory. Attention is directly related to working memory. Furthermore, Zadina [18] observed that working memory capacity was predicted by the ability to control attention, indicating the significance of attention training for enhancing memory processes associated with success. The importance of classroom teaching approaches to improve attention and facilitate learning is supported by empirical evidence. The relationship between working memory and brain activities can be explored by referencing Karl Lashley's experiment [19].

Working memory requires delay or waiting as a defining attribute. When anything occurs, there is a brief delay for working memory, and if the memory is successful, the individual remembers what occurred. Mice from which Karl Lashley had excised a portion of the brain had difficulties navigating a maze. Working memory and attention are mapped by the frontal areas of the brain and are associated with decision-making, turning mental processes into physical behavior [20–22]. The student receives the information, processes and encodes it, and perceives its content based on the cognitive processes he has triggered. Understanding the complexity of the relationships between various brain regions has led to the activation of various synapses. The process of learning enhances the connection between synapses in the brain. Numerous neural pathways contribute to the learning process, as demonstrated by neuroimaging studies that have elucidated the complexity of relationships between various brain regions. A neuroscientist who specializes in education can advise teachers on how to organize lessons utilizing numerous neural pathways and recommend creative tactics to enhance learning [23]. Therefore, educational neuroscience can help teachers organize their classes by reminding them that all components of a cognitive subject utilize brain resources and raise the cognitive load that contributes to learning [24].

Interactions between different regions of the brain and the formation of new neural pathways through the synapses of neurons demonstrate the brain's limitless potential. The integration of diverse cognitive functions facilitates learning and their application through appropriate action. The process of learning turns cognitive processes into individualized behavioral patterns. The many stimuli the brain gets, whether in a school setting or outside of it, form new synapses and strengthen various neural pathways, demonstrating the brain's plasticity. The parts of the sensory cortex concerned with the sensation and perception of stimuli increase the brain's plasticity. Their link to neurons facilitates learning and strengthens behavioral habits. Hillman et al. [25] contend that numerous studies on mice and other non-human species suggest that physical activity and music exposure can increase the number of synapses or even induce the development of new neurons in the region of the hippocampus [26]. Other studies have demonstrated the positive effects of cardiorespiratory exercise on specific aspects of brain function and cognitive ability. Therefore, the acquisition of knowledge gets ever more complex. Not only are brain neurons involved, but also the body's sensory flows and movements. In the Venn diagram depicting the application of Neuroscience findings in the classroom, the student who learns most effectively carefully captures the knowledge and, through sensory inputs, turns it into a behavioral schema, i.e., his direct engagement (Figure 1).

Focusing on how neural synapses change during the learning process and development, neuroimaging research has identified brain neural networks crucial in the development of school-taught abilities such as reading and mathematics. Both anatomical and functional alterations are detected in the brain. Ansari et al. [15] found that 100 hours of remedial instruction in an inclusion department can contribute to changes in the organization of the left hemisphere's white matter in pupils with low reading proficiency between the ages of 8 and 10 as an increase in myelination is noticed. However, the brain also displays indicators of maturity during adulthood, including increased structural neuroplasticity. The possibility of visualizing and capturing the effects of the learning process on the brain encourages the expectation that incorporating experimental studies and expanding knowledge in the field of neuroeducation will contribute to the development of better learning environments that facilitate the optimal acquisition of academic skills.

Bruer [27] and Tandon & Singh [28] have focused on summarizing neuroeducational findings and connecting education with neuroscience through two primary streams of knowledge: The first is concerned with the emergence of brain structures related to educational processes such as reading, arithmetic calculations, language acquisition, and essential cognitive functions such as attention and memory, and the second is concerned with the structural and functional effects of educational processes and cognitive functions on the brain. It is known that learning to read affects the neuroplasticity of the brain because, according to the hypothesis of neuronal recycling, in order to master the reading skill, students must first master the ability to associate sounds and letters (graphophonological correspondence), which is related to the formation of neuronal circuits between brain structures that project to the occipital and auditory cortex (senses of sight and hearing, respectively) [29]. A diagnostic entity belonging to the preceding category is developmental dyslexia, a structural or functional disease of the reading neural network. Early identification and rigorous, tailored remedial intervention contribute significantly to the mastery of reading skills in this population of kids. It is important to note that neuroeducation must give teachers specific, situation-specific instructions. However, a comprehensive understanding of the physiology and function of the brain leads to a teacher's readiness to properly manage diversity in the classroom. Class and showcasing the talents of students with specific learning challenges, facilitating their assimilation into the educational community [30, 31].

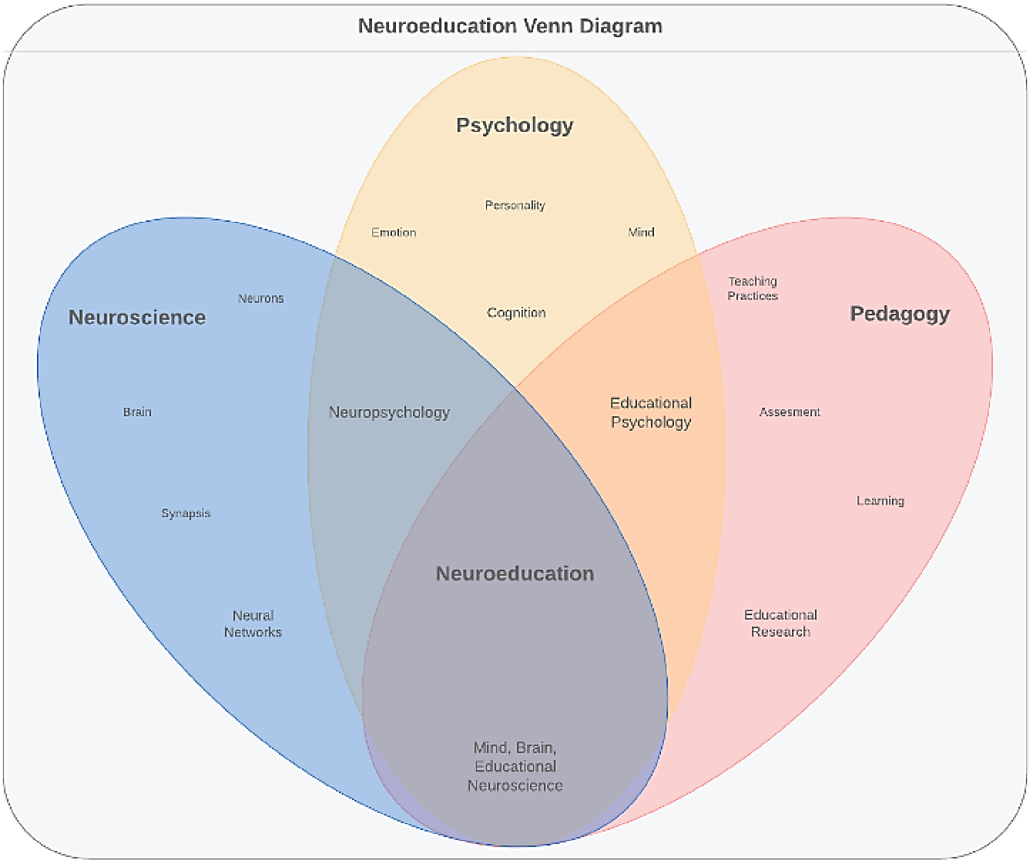

Figure 1. Neuroeducation Venn Diagram

Moreover, the field of neuroscience focuses not only on the study of cognitive mechanisms as a component of brain function but also on the study of behavior and mechanisms associated with emotion and awareness, such as decision-making and self-regulation, which play a crucial role in the educational process [32]. According to earlier research [30], instructors and the educational community as a whole must determine what they need to know about the field of neuroscience and how they may use this knowledge to assist their pupils. According to Tokuhama-Espinosa & Nouri [33], there are six universal concepts concerning the mind, brain, and education that instructors might benefit from knowing:

Each human brain is composed of a unique combination of genetic structure and life experiences; each brain is uniquely equipped to learn; experience influences the acquisition of new knowledge; the brain undergoes constant changes as a result of experience; neuroplasticity is a dynamic process that varies with age; memory and attention are necessary for the learning process.

In this light, everything is now evident. Following the adoption of neuroeducational interventions, studies [34] have reported the construction of educational platforms for teacher training programs with simultaneous evaluation of student outcomes. Knowland [30] and JohnBull [31] have highlighted the construction of a fifteen-hour teacher-tailored introductory neuroscience training workshop or the integration of neuroscience courses in university school curricula. Incorporating neuroscience-based instruction shifts the focus of the learning process to a learner-centered framework and their needs [6, 34, 35], while at the same time enhancing their social and moral development, as suggested by Kalra & O'Keeffe [36] by researchers who used a neuroeducational model to investigate the relationship between the functional language use of students from various school contexts. Other researchers have discovered a correlation between the implementation of a neuroeducation program and a shift in the beliefs and behaviors of teachers, as well as an improvement in students' math performance [30, 32]. Some researchers advocate developing a single, universal model of neuroeducation in authentic learning situations while simultaneously observing the development of students' fundamental skills [36].

On the basis of the foregoing, the present systematic metadata review aims to investigate the connection between neuroscience and education in order to analyze the current situation and propose future pathways for the development of such bridging and communication between the two knowledge bases.

3- Research Design and Methodolgy

The objective of this study is to present articles and studies concerning the link between the development of neuroscience and the enhancement of the educational process by conducting a thorough metadata review of digitally relevant literature sources. Specifically, researchers screened for articles discussing how neuroscience influences the enhancement of the education process. The research approach is illustrated in Figure 2.

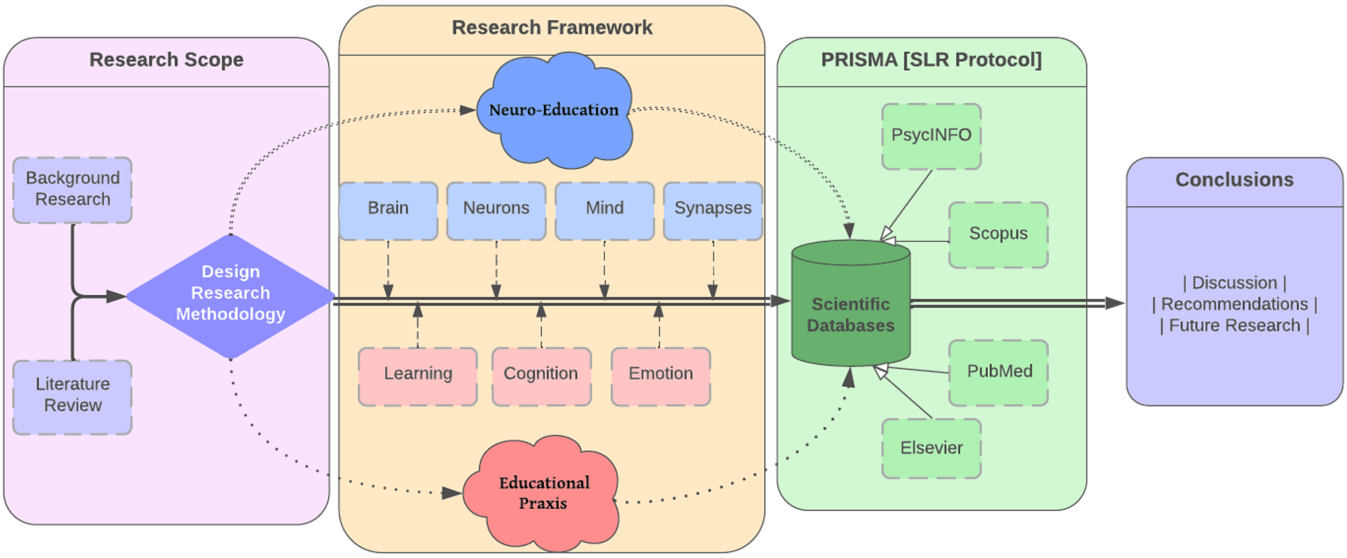

Figure 2. Research Methodology Flowchart

Based on a search of worldwide literature published between 2000 and 2022, the present effort is a PRISMA-based systematic review of metadata. The search was conducted utilizing global data sources (PubMed, PsycINFO, Scopus, and Elsevier). The search terms included "neuroscience", "education", "neuroeducation", "pedagogy", and "educational neuroscience."

This review included studies that: (a) addressed the relationship between neuroscience and the educational process; (b) were conducted within the aforementioned time period; and (c) addressed the findings of educational process intervention studies. In this work, the PRISMA approach was used to conduct a systematic literature review. After preliminary evaluations were made prior to this review, the first step of the data collection process was to identify the keywords. Specific use was made of the following keywords: neuroscience, education, neuroeducation, pedagogy, and educational neuroscience.

The papers were then indexed in the most famous and well-known research databases, such as Scopus, PubMed, Elsevier, and PsychINFO. There were a total of 86 (N=86) searches based on keyword combinations disclosed by a search. In the second stage (Step=2), the inclusion criteria for screening the surveys were the article's title and a summary relating to the predetermined keywords. This stage resulted in the production of fifty-eight (N=58) papers that matched the inclusion criteria stated previously. In step three (Step=3), items with inaccessible or difficult-to-find full texts (N=33) were removed.

In addition, they were rejected owing to linguistic limitations (N=6); specifically, works having content written in a language other than English were omitted. This screening considered the following criteria: studies must have been written in English, published between 2010 and 2022, and have practical implications for neuroleadership research or conceptual discussions. There were a total of nineteen works (N=19) that met the aforementioned criteria. Due to a dearth of study data, six (N=6) research papers were omitted from step four (Step=4).

These studies made no direct links between neuroeducation and learning; hence, their implications were omitted from the research group designated by the "Data Quality Score" in the flowchart. The primary themes of the study were determined by evaluating the papers. Neuroeducation and educational consequences were included as themes if they were also supported by other papers that were analyzed (Figure 3).

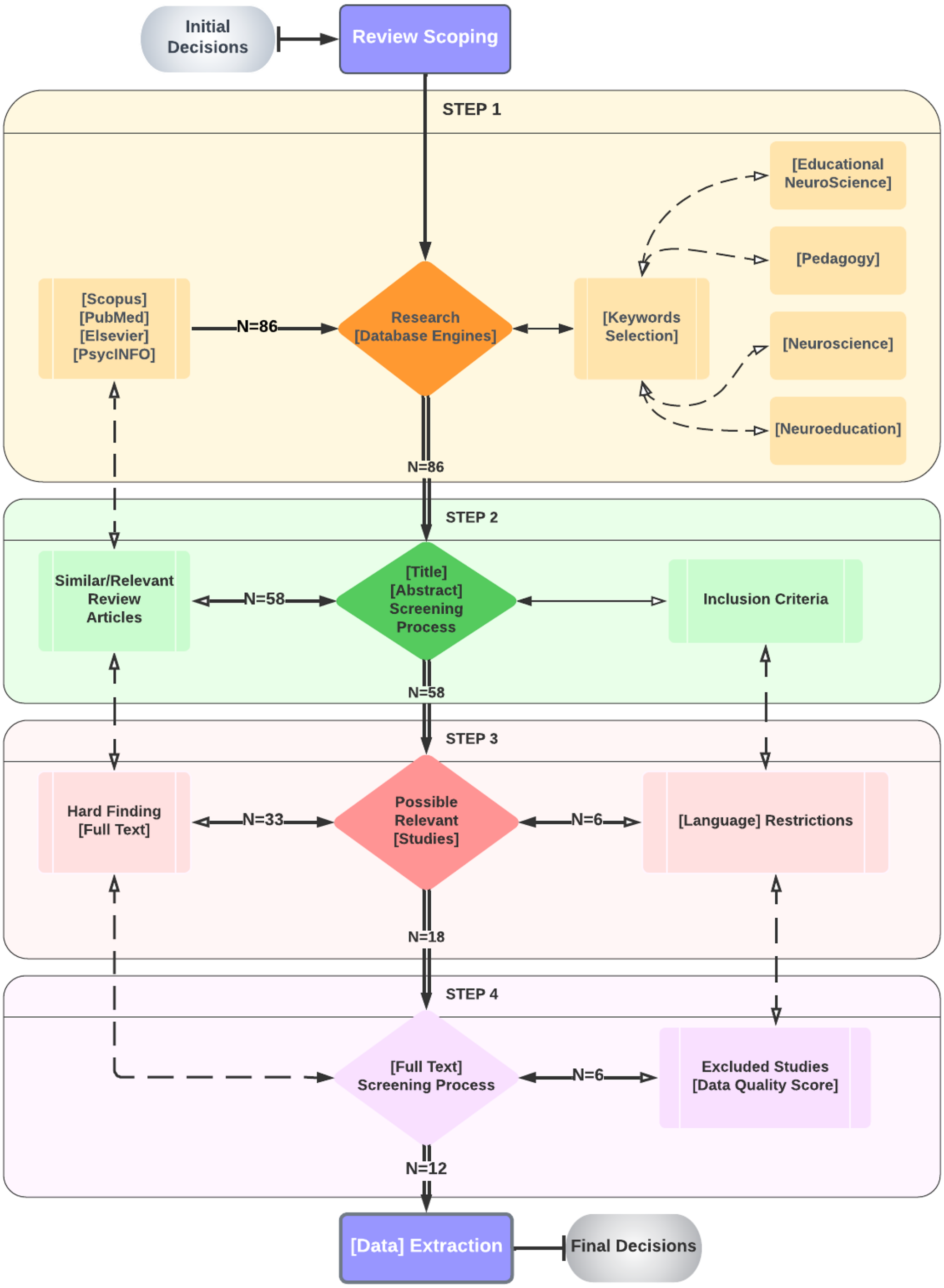

Figure 3. PRISMA Flowchart

4- Results and Discussion

The overall twelve studies considered in the review are summarized in Table 1. The particular research works are then evaluated. The article review analysis illustrates the irreconcilable relationship between educational research, the psychology of learning, and the neuroscience of learning [27]. Educational neuroscience is currently located between neuroscientific and psychological research. However, it is not an important topic in the educational research literature. In the psychological literature, educational neuroscience, educational research, and biological science are intricately intertwined to provide a comprehensive learning research agenda. To comprehensively understand how the brain functions, scientists must engage in an unprecedented level of international interdisciplinary collaboration. The developing interdisciplinary area of educational neuroscience strives to integrate neuroscience, psychology, and cognitive science with educational technology [28]. This article examines the expansive relationship between education and the "Brain Sciences," which include neuroscience, child psychology, and cognitive science. According to Kalra & O'Keeffe [37], "The relationship between the brain sciences and education is extensive and developing. Neuroplasticity is the essential bridging process, and its molecular, neurological, and brain mechanisms should be studied in greater depth in the future." According to Dehaene & Changeux [38], human cognitive neuroscience has made tremendous advances in understanding the specific brain circuits that underpin diverse learning domains, such as mathematics, reading, and language acquisition. Cognitive scientists and philosophers of science [27] are among many who question the label "Educational Neuroscience" and aim to regard child psychology, neuroscience, and cognitive science as distinct sciences.

Table 1. List of Screening Research Articles

Research Study	Title of Study	Participants / Intervention	Conclusions (synopsis)
Rato et al. (2011) [39]	Achieving a successful relationship between Neuroscience and Education: The views of Portuguese teachers	The study was carried out in Portugal with 30 participating schools, and 627 questionnaires were answered by teachers from Preschool to High School	Teachers believe that: ▪ Neuroscience could be an ally of their work ▪ There is a similar pattern of acceptance of neuroscience majors regardless of their area of expertise, location of practice, or years of experience ▪ There is a need for further education to succeed in this new scientific field
Jamaludin et al. (2019) [40]	Educational neuroscience: bridging theory and practice	Review study based on existing literature and authors' observations	Although neuroscience research has developed positively, the application of various targeted and effective intervention methodologies in the educational process, and collaborations between other fields of study, such as clinical and behavioral research, are prominent to add a more holistic understanding of learning processes of formal and informal development
Thomas et al. (2019) [1]	Annual Research Review: Educational neuroscience: progress and prospects	Review study based on existing literature and authors' observations	Analysis of the origins of educational neuroscience, and presentation of the main areas of research activity and the main challenges it faces as a translational field They respond to major criticisms in the field that include a priori arguments against the relevance of neuroscience to education
Tandon et al. (2016) [28]	Educational Neuroscience: Challenges and Opportunities	A review study of the present situation in India	To successfully implement any neuroscience program in education, teachers, educators, child psychologists, and cognitive neuroscientists must work together.
Thomas (2013) [41]	Educational neuroscience in the near and far future: Predictions from the analogy with the history of medicine	Analysis and discussion on the topic of educational neuroscience	Neuroscience can categorize children and help substantially in the educational process, especially in difficult cases of learning disabilities. This study proposes six ways to target such cases.
Scoffham et al. (2011) [42]	Happiness matters: towards a pedagogy of happiness and well-being	Analysis of 2 cases of application of neuroscience in the educational process	This study highlights the role of joy and happiness in improving the educational process and learning. Joy, because of neurotransmission in the brain, can facilitate memory and learning
Rueda (2020) [43]	Neuroeducation:Teaching with the brain	Article analyzing the situation theoretically	The emerging field of educational neuroscience aims to combine information about brain processes related to cognitive skills involved in learning with the educational community's efforts to optimize the transmission and assimilation of knowledge. This study summarizes the molecular basis of the connection between the two sciences.
Bruer (2015) [27]	Where Is Educational Neuroscience?	Review article of existing studies in the literature	The psychology literature fundamentally links educational neuroscience, research, and neuroscience into a comprehensive learning opportunity.
Ansari et al. (2011) [15]	Neuroeducation – A Critical Overview of An Emerging Field	Review article	This article analyzes educational process factors such as Reading, Reading, Mathematics, and "Brain Training", with many additions from the neurosciences. In particular, cognitive neuroscience studies are moving toward improving how the brain and cognition alter learning.
Zadina (2015) [18]	The emerging role of educational neuroscience in education reform	Review article on ways to improve the relationship of neuroscience to education	This article explores proposals for appropriate Educational Neuroscience training. These broad Educational Neuroscience-based interventions could reform the curriculum and new ways that the Educational Neuroscientist can inform the professional educator.
Nishi et al. (2016) [44]	The Global Challenge in Neuroscience Education and Training: The MBL Perspective	Literature review and news analysis article	MBL courses offer fertile educational grounds for neuroscience. These courses support interdisciplinary education, combining scientists and educators, exceptional depth and breadth with access to the most critical new technologies.
Goswami (2006) [12]	Neuroscience and education: from research to practice?	Research article	The development of neurosciences with imaging methods of the brain in cases of dyslexia or learning difficulties has helped the educational process in the classroom.

Jamaludin et al. (2019) [40] studied advancements in educational neuroscience were described as exciting, and their potential contribution to educational practices was highlighted. Educational neuroscience draws on a plethora of evidence-based scientific understandings of brain-behavior interactions to inform the development of novel teaching and learning methodologies. However, the direct contribution of educational neuroscience to teacher training and classroom practice remains minimal. Horvath et al. (2017) [45] emphasized that while there may be multiple causes, the lack of a proper translation framework from theoretical laboratory research to successful teaching and learning practices in 'complex' classrooms is a primary concern. While theoretical developments have led to controlled laboratory trials with the potential to improve education, the translation of these endeavors into effective teaching and learning practices that have a positive influence on students in classrooms remains difficult [43].

Particularly, gaining a comprehensive understanding of how the brain functions will necessitate a level of international interdisciplinary collaboration never seen before. The inquiry into MBL (Marine Biological Laboratory) course programs by Nishi et al. [44] suggests this. To accomplish this, we must "attract, educate, and cultivate" the most intelligent and diverse students in biology, psychology, chemistry, physics, computational science, engineering, and mathematics [46]. In these courses, postgraduate, postdoctoral, and trainee students receive intensive, brief, and practical training in a variety of scientific disciplines. In biomedical fields such as cell biology, developmental biology, microbiology, genetics, and neuroscience, these contributions have a strong track record of producing new leaders.

According to Rato et al. [39], there have been numerous attempts since the 1960s to link Neuroscience and Education [47]. The term "neuro-educators" was coined thirty years ago on the premise that brain science may change and enhance classroom practice. However, the importance of Neuroscience in Education remains controversial [48, 49]. Decades of primary education have emphasized behavioral patterns, reflecting cognitive psychology's contributions [50]. Due to the fact that there is no learning without the study of the brain [12], modern research on learning processes must eventually link Education to Neuroscience. Educators are now confronted with a new dilemma: how to merge the philosophy and practice of Neuroscience and Education. In this study, a questionnaire was developed to analyze teachers' perspectives on Neuroscience and Education [51, 52].

The academic field has had substantial development and growth in recent decades, merging education with neuroscience. According to Ansari et al. [15], the concept of learning is essential to research programs in this field, and interdisciplinary work has emerged at the intersection of education, cognitive psychology, and cognitive neuroscience. Ambivalent disciplinary principles and structures are still reflected in a variety of titles, such as "educational neuroscience" [53], "mind, brain, and education", and "neuroeducation" [15], "neuroeducational research" [54], "neuroscience" [55], and "pedagogical neuroscience" [56]. Consequently, the field that combines education with neuroscience appears to be evolving, where one can find a complex web of academic structures, relationships, and actors with varying perceptions, principles, and values.

Thomas (2013) [41] examined the relationship between education and neuroscience to improve learning and teaching. They examined the reasoning behind these integrated research projects. They discuss current results regarding the brain circuits underlying reading and arithmetic abilities and the potential for employing neuroscience to develop training programs for neurocognitive processes such as working memory, which is expected to influence overall brain function. Specifically, they stress realistic expectations regarding the direct impact of neuroscience on education, methodological problems, and the need for multidisciplinary training, which leads to restrictive communication between educators and neuroscientists. Even if there are numerous obstacles, there is confidence, and the framework has been prepared for developing this sector's expansion.

According to Goswami [12], education is a fundamental and defining trait of humans. Neuroimaging advancements have assisted in comprehending the peculiarities of the human brain and how they connect to a desire for information sharing. The human brain evolved to support cognitive abilities that facilitate social learning. Consequently, education and experience have a substantial effect on the development of the human brain. The emerging area of Neuroeducation seeks to integrate research about brain processes related to cognitive skills involved in learning with the educational community's efforts to maximize knowledge transmission and assimilation [57].

According to Scoffham & Barnes [42] study, joy and happiness matter. Numerous individuals make personal fulfillment and happiness their primary life objectives. In general, parents prioritize their children's happiness and enjoyment of childhood events. This paper examined theoretical and practical perspectives on the development of a pedagogy of happiness and well-being in educational contexts. The cornerstones of the research were as follows: a) The function of emotions in cognition; b) The impact of a specific emotion—happiness—on children's lives and learning [58]; and c) How curriculum and classroom practice may actively aim to design pedagogies that encourage positive outcomes.

According to the argument, a greater focus on happiness and well-being could lead the vast majority of students and teachers to more prosperous and meaningful learning experiences. A relatively minor improvement on the happiness-frustration continuum might drastically reduce the proportion of children on the opposite end of the scale. Educators are encouraged to trust their professional judgment by offering an examination of existing research and adding the writers' perspectives.

The Thomas et al. [1] study concludes that educational neuroscience is an interdisciplinary research field that tries to convert research discoveries concerning neural learning mechanisms into educational practice. Comparable domains employ behavioral regulation, decision-making, reward, empathy, and moral reasoning research [59] to transfer the discoveries of neuroscience and neuropsychology into law, economics, mental health, and social policy [60, 61]. Despite significant criticism [10] and significant ongoing debate [11] regarding the usefulness of bringing information from neuroscience research to educational difficulties, potential linkages between neuroscience and education are being actively researched around the world. Various definitions, such as neuroeducation, educational neuroscience, mind, brain, and education, have been used to describe these endeavors. Nonetheless, bringing brain research into education requires considerable effort.

The progress that educational neuroscience has made over the years is reviewed, emphasizing how neuroscience has shaped our more profound understanding of children's education and numeracy development by shedding light on brain development through the study of educational processes and the enhancement of instructional decisions. Placing these discussions within the framework of learning disabilities such as dyslexia and math difficulties, information on the cognitive and neurological mechanisms that may underlie these ailments was provided without discounting their potential applications to children. Future uses of neuroscience in the early identification of learning issues in children, as well as challenges that may arise in the field of educational neuroscience, are highlighted. In addition, it was emphasized that although neuroscience research has made positive strides, the application of various targeted and effective intervention methodologies and collaborations with other fields of study, such as clinical and behavioral research, are essential for a more comprehensive understanding of the learning processes underlying formal and informal development cases.

In the context of educational neuroscience, JohnBull (2022) [31] provided insights on the crucial balance required between neuroscience and learning science. In their analysis of how educational neuroscience has influenced theories of learning, they emphasized the importance of curriculum, teaching, learning, and evaluation as educational concepts. As we progress toward the incorporation of neuroscience into education, and as this incorporation is driven by an orientation, scientifically sound design is urged more and more. Additionally, pupils' optimal learning settings must be addressed. This research in the science of learning is mediated by teacher preparation, skill, and adaptability in extending the range of instructional approaches, which incorporates educational neuroscience's adept comprehension of students' intricate requirements.

5- Conclusions

Neuroscience is related to other sciences as a field that supports educational practice and the learning process. In the original analysis, it was identified as a field that connects the neurosciences with education, psychology, and neurophysiology. It is related to neuroscientific-psychological research on learning mechanisms that neuroscientists and educators have an interest in, specifically the role of emotion and rational thought in effective learning. In addition, the academic community affiliated with neuroscience is linked to research on working memory and cognition. This is a brand-new and precarious relationship that will certainly get better over time. The effects of neuroscience research on science education, cognitive load, classroom motivation, and educational environments remain to be determined.

Neurotraining can strengthen the fundamental skills of pupils during the educational process. Students can make significant gains in reading, mathematics, and empathy, as demonstrated by studies that implemented neurotraining programs before and after the intervention, demonstrating the utility of a neuroscience training program for teachers as a preliminary step to improving students' core competencies. Improving empathy as part of social, emotional, and moral competencies through neurotraining may be more associated with the development of executive functions and self-regulation abilities. Therefore, neurotraining looks capable of developing and promoting cognitive and emotional learning parameters, including decision-making, self-regulation, and social and emotional parameters in general. Moreover, cognitive flexibility as an efficiency parameter that facilitates the management of reading and thinking processes through metacognitive skills can have a substantial impact on social and emotional capacities such as empathy, hence facilitating social interactions. Clearly, neuroeducation contributes significantly to the cognitive and emotional systems involved in learning, hence fostering cooperative learning. By incorporating experimental design studies into actual school settings, advances in neuroeducational research can provide a foundation for enhancing classroom teaching techniques.

Consequently, it is evident that the connection between neuroscience data and the practice of the educational process is crucial, especially when it comes to learning challenges or giftedness characteristics that require highly targeted, relevant, and personalized intervention.

5-1- Future Research

Due to continually changing socioeconomic conditions (e.g., the pandemic), the digital transformation with the establishment of interactive classrooms, and data from the field of educational neuroscience, the educational landscape is in perpetual flux. Educational leaders are required to be current on the most recent research findings and to develop creative teaching and learning practices based on their understanding of neuroscience. Knowledge of the learning mechanisms of the brain is likely to increase and inspire fresh enthusiasm for teaching in schools. The translation of neuroscientific results, as well as their modification and further use by the educational community, is a challenging endeavor. The relationship between neuroscience and educational science is mismatched. The mismatch is due to the complexity of basic science, given the various learning systems in the brain and the elements that influence their operation, and the difficulty of translating that complexity into the classroom. There exists a model for how this translation can be executed.

According to Roediger (2013) [29], a translational educational science may be comparable to medicine, "A field in which laboratory and animal research discoveries are tested in small-scale human studies and subsequently in larger-scale clinical trials. If the medicines pass these tests, they are introduced into clinical practice (with the findings, such as side effects, continuing to be monitored)"– and according to Roediger, might result in medical advancements comparable to those of the last century. In this direction, the United Kingdom has funded research projects based on the design described above (Wellcome Trust, Educational Endowment Foundation, 2014), which has advantages but also several ethical limitations related to the way and source of design for these learning activities-intervention trials that are based on the translation of neuroscience data into educational practice, as well as ethical limitations and principles from the use of predilection (e.g., low achievement motivation, feeling of inadequacy). The majority of educational neuroscience research has been conducted in developed nations. In developing nations, however, educational achievements may be more dependent on social and even nutritional variables. Consequently, a larger understanding of social and political factors, not simply cognitive neuroscience factors, is required.

Finally, educational neuroscience as a field must determine how to respond to the (welcome) desire of policymakers to include components of neuroscience into legislation. Early assessments of the field questioned the impact of research, in this case studies on sensitive times of brain development, on early years of education policymaking. In many industrialized countries with organized education systems, such as the United Kingdom and Finland, policymakers still desire to include cognitive neuroscience results in order to make decisions based on evidence. A significant obstacle is the necessity to develop a substantial and convergent evidence base (e.g., an educational information system) to lend scientific (and, ideally, economic) weight to policy proposals. In fact, in certain areas of educational neuroscience, such as the long-term negative impacts of early toxic stress, the evidence is sufficient to inform policy (Center on the Developing Child at Harvard University, 2017). However, more precise ideas for change may require a quicker implementation time. The rate at which new policies and standards are implemented in schools and clinics is typically slow. Engaging with policymakers, in combination with the implementation of experimental research in the field of neuroeducation, is a future objective and a significant challenge for educational neuroscience researchers.

6- Declarations

6-1- Author Contributions

Conceptualization, E.G., I.D., C.H., and H.A.; methodology, E.G., I.D., C.H., and H.A.; resources, E.G., I.D., C.H., and H.A.; writing—original draft preparation, E.G., I.D., C.H., and H.A.; writing—review and editing, E.G., I.D., C.H., and H.A. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

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6-4- Institutional Review Board Statement

Not applicable.

6-5- Informed Consent Statement

Not applicable.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

7- References

[1] Thomas, M. S. C., Ansari, D., & Knowland, V. C. P. (2018). Annual Research Review: Educational neuroscience: progress and prospects. Journal of Child Psychology and Psychiatry, 60(4), 477–492. doi:10.1111/jcpp.12973.

[2] Gkintoni, E., Halkiopoulos, C., & Antonopoulou, H. (2022). Neuroleadership as an Asset in Educational Settings: An Overview. Emerging Science Journal, 6(4), 893–904. doi:10.28991/ESJ-2022-06-04-016.

[3] Antonopoulou, H., Halkiopoulos, C., Barlou, O., & Beligiannis, G. N. (2019). Transition from educational leadership to e-leadership: A data analysis report from TEI of western Greece. International Journal of Learning, Teaching and Educational Research, 18(9), 238–255. doi:10.26803/ijlter.18.9.13.

[4] Carvalho, A., Alves, H., & Leitão, J. (2022). What research tells us about leadership styles, digital transformation and performance in state higher education?. International Journal of Educational Management, 36(2), 218-232. doi:10.1108/IJEM-11-2020-0514.

[5] Antonopoulou, H., Halkiopoulos, C., Barlou, O., & Beligiannis, G. N. (2020). Leadership types and digital leadership in higher education: Behavioural data analysis from University of Patras in Greece. International Journal of Learning, Teaching and Educational Research, 19(4), 110–129. doi:10.26803/ijlter.19.4.8.

[6] Halkiopoulos, C., Gkintoni, E., & Antonopoulou, H. (2023). Neuroeducation and Artistic Expression. An Overview from the Biopsychology Viewpoint. Technium Education and Humanities, 3(1), 38–49. doi:10.47577/teh.v3i1.8235.

[7] Thorndike, E.L. (1926). Educational psychology. Volume 1: The original nature of man. Ph.D. Thesis, Teachers College, New York, United States.

[8] Jones, E. G., & Mendell, L. M. (1999). Assessing the decade of the brain. Science, 284(5415), 739. doi:10.1126/science.284.5415.739.

[9] Varma, S., McCandliss, B. D., & Schwartz, D. L. (2008). Scientific and Pragmatic Challenges for Bridging Education and Neuroscience. Educational Researcher, 37(3), 140–152. doi:10.3102/0013189x08317687.

[10] Bishop, C. L., Abraham, I., Tyler, J., & Bishop, C. M. (2014). Exploring Juvenile Delinquency: Educational, Psychological, and Cognitive Outcomes. PsycEXTRA Dataset. doi:10.1037/e557352014-001.

[11] Gabrieli, J. D. E. (2016). The promise of educational neuroscience: Comment on Bowers (2016). Psychological Review, 123(5), 613–619. doi:10.1037/rev0000034.

[12] Goswami, U. (2006). Neuroscience and education: From research to practice? Nature Reviews Neuroscience, 7(5), 406–411. doi:10.1038/nrn1907.

[13] Feiler, J. B., & Stabio, M. E. (2018). Three pillars of educational neuroscience from three decades of literature. Trends in Neuroscience and Education, 13, 17–25. doi:10.1016/j.tine.2018.11.001.

[14] Wilcox, G., Morett, L. M., Hawes, Z., & Dommett, E. J. (2021). Why Educational Neuroscience Needs Educational and School Psychology to Effectively Translate Neuroscience to Educational Practice. Frontiers in Psychology, 11, 618449. doi:10.3389/fpsyg.2020.618449.

[15] Ansari, D., De Smedt, B., & Grabner, R. H. (2012). Neuroeducation - A critical overview of an emerging field. Neuroethics, 5(2), 105–117. doi:10.1007/s12152-011-9119-3.

[16] Goldstein, T. R., & Filipe, A. (2018). The interpreted mind: Understanding acting. Review of General Psychology, 22(2), 220–229. doi:10.1037/gpr0000116.

[17] Atteveldt, N., Peters, S., De Smedt, B., & Dumontheil, I. (2020). Towards Greater Collaboration in Educational Neuroscience: Perspectives From the 2018 Earli-SIG22 Conference. Mind, Brain, and Education, 14(2), 124-129. doi:10.1111/mbe.12250.

[18] Zadina, J. N. (2015). El papel emergente de la neurociencia educativa en la reforma de la educación. Psicologia Educativa, 21(2), 71–77. doi:10.1016/j.pse.2015.08.005.

[19] Niese, A. T. (2008). The Relationship between visual working memory and visual long-term memory. Ph.D. Thesis, The University of Iowa, Iowa City, United States doi:10.17077/etd.ef11mic4.

[20] Gkintoni, E., & Dimakos, I. (2022). An Overview of Cognitive Neuroscience in Education. EDULEARN22 Proceedings. doi:10.21125/edulearn.2022.1343.

[21] Glimcher, P., & Fehr, E. (2014). Preface. Neuroeconomics, ix–xi, Academic Press, Cambridge, United States. doi:10.1016/b978-0-12-416008-8.00038-3.

[22] Halkiopoulos, C., Antonopoulou, H., Gkintoni, E., & Aroutzidis, A. (2022). Neuromarketing as an Indicator of Cognitive Consumer Behavior in Decision-Making Process of Tourism destination—An Overview. Transcending Borders in Tourism Through Innovation and Cultural Heritage, Springer Proceedings in Business and Economics. Springer, Cham, Switzerland. doi:10.1007/978-3-030-92491-1_41.

[23] Cruickshank, W. M. (1981). A new perspective in teacher education: the neuroeducator. Journal of Learning Disabilities, 14(6), 337–341. doi:10.1177/002221948101400613.

[24] Gkintoni, E., Meintani, P. M., & Dimakos, I. (2021). Neurocognitive And Emotional Parameters in Learning and Educational Process. ICERI Proceedings. doi:10.21125/iceri.2021.0659.

[25] Hillman, K. L., Doze, V. A., & Porter, J. E. (2006). α adrenergic activation of GABAergic interneurons in region CA1 of the rat hippocampus. The FASEB Journal, 20(4). doi:10.1096/fasebj.20.4.a246-a.

[26] Papadakakis, A., Sidiropoulou, K., & Panagis, G. (2019). Music exposure attenuates anxiety- and depression-like behaviors and increases hippocampal spine density in male rats. Behavioural Brain Research, 372, 112023. doi:10.1016/j.bbr.2019.112023.

[27] Bruer, J. T. (2016). Where Is Educational Neuroscience? Educational Neuroscience, 1, 237761611561803. doi:10.1177/2377616115618036.

[28] Tandon, P. N., & Singh, N. C. (2016). Educational neuroscience: Challenges and opportunities. Annals of Neurosciences, 23(2), 63–65. doi:10.1159/000443560.

[29] Roediger, H. L. (2013). Applying cognitive psychology to education: Translational educational science. Psychological Science in the Public Interest, Supplement, 14(1), 1–3. doi:10.1177/1529100612454415.

[30] Knowland, V. (2020). Educational Neuroscience. Educational Neuroscience, 474–499. doi:10.4324/9781003016830-24.

[31] JohnBull, R. (2022). Neuroeducation for Social Justice: Integrating Culturally Relevant Pedagogy and Neuroeducation Instructional Practices. Proceedings of the 2022 AERA Annual Meeting. doi:10.3102/1894084.

[32] Potvin, P., & Borst, G. (2018). Executive functions and academic learning. Neuroeducation, 5(2), 42–43. doi:10.24046/neuroed.20180502.42.

[33] Tokuhama-Espinosa, T., & Nouri, A. (2020). Evaluating what Mind, Brain, and Education has taught us about teaching and learning. ACCESS: Contemporary Issues in Education, 40(1), 63–71. doi:10.46786/ac20.1386.

[34] Stamatiou, Y. C., Halkiopoulos, C., Giannoulis, A., & Antonopoulou, H. (2022). Utilizing a Restricted Access e-Learning Platform for Reform, Equity, and Self-development in Correctional Facilities. Emerging Science Journal, 6, 241–252. doi:10.28991/esj-2022-sied-017.

[35] Vélez, J. C. L., & Villafuerte Holguin, J. S. (2021). Educational innovation into english as a foreign language practices for early children: neuroeducation and the total physical response method. Education Quarterly Reviews, 4(3), 377-389. doi:10.31014/aior.1993.04.03.346.

[36] Global Scientific Production on Neuroeducation: An Analysis in Scopus, 2010 – 2020. (2022). NeuroQuantology, 20(3), 126–134. doi:10.14704/nq.2022.20.3.nq22052.

[37] Kalra, P., & O'Keeffe, J. K. (2011). Communication in mind, brain, and education: Making disciplinary differences explicit. Mind, Brain, and Education, 5(4), 163–171. doi:10.1111/j.1751-228X.2011.01124.x.

[38] Dehaene, S., & Changeux, J. P. (2011). Experimental and Theoretical Approaches to Conscious Processing. Neuron, 70(2), 200–227. doi:10.1016/j.neuron.2011.03.018.

[39] Rato, J. R., Abreu, A. M., & Castro-Caldas, A. (2011). Achieving a successful relationship between Neuroscience and Education: The views of Portuguese teachers. Procedia - Social and Behavioral Sciences, 29, 879–884. doi:10.1016/j.sbspro.2011.11.317.

[40] Jamaludin, A., Henik, A., & Hale, J. B. (2019). Educational neuroscience: bridging theory and practice. Learning: Research and Practice, 5(2), 93–98. doi:10.1080/23735082.2019.1685027.

[41] Thomas, M. S. C. (2013). Educational neuroscience in the near and far future: Predictions from the analogy with the history of medicine. Trends in Neuroscience and Education, 2(1), 23–26. doi:10.1016/j.tine.2012.12.001.

[42] Scoffham, S., & Barnes, J. (2011). Happiness matters: Towards a pedagogy of happiness and well-being. Curriculum Journal, 22(4), 535–548. doi:10.1080/09585176.2011.627214.

[43] Rueda, C. (2020). Neuroeducation: Teaching with the brain. Journal of Neuroeducation, 108–113. doi:10.1344/joned.v1i1.31657.

[44] Nishi, R., Castañeda, E., Davis, G. W., Fenton, A. A., Hofmann, H. A., King, J., Ryan, T. A., & Trujillo, K. A. (2016). The Global Challenge in Neuroscience Education and Training: The MBL Perspective. Neuron, 92(3), 632–636. doi:10.1016/j.neuron.2016.10.026.

[45] Horvath, J. C., Horton, A. J., Lodge, J. M., & Hattie, J. A. C. (2017). The impact of binge watching on memory and perceived comprehension. First Monday. doi:10.5210/fm.v22i9.7729.

[46] Akil, H., Balice-Gordon, R., Cardozo, D. L. L., Koroshetz, W., Posey Norris, S. M. M., Sherer, T., Sherman, S. M., & Thiels, E. (2016). Neuroscience Training for the 21st Century. Neuron, 90(5), 917–926. doi:10.1016/j.neuron.2016.05.030.

[47] Wise, S. P., & Willingham, D. T. (2009). Motor skill learning. In Encyclopedia of Neuroscience, 1057–1066. doi:10.1016/B978-008045046-9.00774-9.

[48] Fischer, K. W., Goswami, U., & Geake, J. (2010). The Future of Educational Neuroscience. Mind, Brain, and Education, 4(2), 68–80. doi:10.1111/j.1751-228X.2010.01086.x.

[49] Samuels, B. M. (2009). Can the differences between education and neuroscience be overcome by Mind, Brain, and Education? Mind, Brain, and Education, 3(1), 45–55. doi:10.1111/j.1751-228X.2008.01052.x.

[50] Piaget, J. (2007). The origins of intelligence in children. W. W. Norton & Company, New York, United States. doi:10.1037/11494-000.

[51] Antonopoulou, H., Halkiopoulos, C., Gkintoni, E., & Katsimpelis, A. (2022). Application of Gamification Tools for Identification of Neurocognitive and Social Function in Distance Learning Education. International Journal of Learning, Teaching and Educational Research, 21(5), 367–400. doi:10.26803/ijlter.21.5.19.

[52] Gkintoni, E., Halkiopoulos, C., Antonopoulou, H., & Petropoulos, N. (2021). Gamification of Neuropsychological Tools as a Multi-Sensory Approach to Education. Stroop's Paradigm. Technium Romanian Journal of Applied Sciences and Technology, 3(8), 92–102. doi:10.47577/technium.v3i8.4798.

[53] Campbell, S. R. (2011). Educational Neuroscience: Motivations, methodology, and implications. Educational Philosophy and Theory, 43(1), 7–16. doi:10.1111/j.1469-5812.2010.00701.x.

[54] Howard-Jones, P. A. (2011). A multiperspective approach to neuroeducational research. Educational Philosophy and Theory, 43(1), 24–30. doi:10.1111/j.1469-5812.2010.00703.x.

[55] Petitto, L. A. (2009). New discoveries from the bilingual brain and mind across the life span: Implications for education. Mind, Brain, and Education, 3(4), 185–197. doi:10.1111/j.1751-228X.2009.01069.x.

[56] Fawcett, A. J., & Nicolson, R. I. (2007). Dyslexia, learning, and pedagogical neuroscience. Developmental Medicine and Child Neurology, 49(4), 306–311. doi:10.1111/j.1469-8749.2007.00306.x.

[57] Erhan, T., Uzunbacak, H. H., & Aydin, E. (2022). From conventional to digital leadership: exploring digitalization of leadership and innovative work behavior. Management Research Review, 45(11), 1524-1543. doi:10.1108/MRR-05-2021-0338.

[58] Gkintoni, E., Boutsinas, B., & Kourkoutas, E. (2022). Developmental Trauma and Neurocognition in Young Adults: A Systematic Review. EDULEARN22 Proceedings. doi:10.21125/edulearn.2022.1332.

[59] Conill, J. (2019). Must Ethics for Moral Neuroeducation Be Naturalistic?. Moral Neuroeducation for a Democratic and Pluralistic Society, Springer, Cham, Switzerland. doi:10.1007/978-3-030-22562-9_1.

[60] Gkintoni, E., Koutsopoulou, I., Antonopoulou, H., & Christopoulos, P. (2021). Consequences Of The Covid-19 Pandemic On Greek Students' Mental Health: Quality Of Life And Trauma Stressful Events Correlation. ICERI Proceedings. doi:10.21125/iceri.2021.0663.

[61] Gkintoni, E., Pallis, E. G., Bitsios, P., & Giakoumaki, S. G. (2017). Neurocognitive performance, psychopathology and social functioning in individuals at high risk for schizophrenia or psychotic bipolar disorder. Journal of Affective Disorders, 208, 512–520. doi:10.1016/j.jad.2016.10.032.