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Educational Neuroscience in Academic Environment. A Conceptual Review

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Abstract. Neuroscience uses cellular and molecular biology, anatomy and physiology, human behavior and cognition, and other disciplines to map the brain at a mechanistic level. Mapping all the cell-to-cell communication networks — the brain circuits that process all thoughts, emotions, and behaviors — is one of the most significant challenges of contemporary neuroscience. Neuroplasticity, the brain's capacity to form new neural connections and circuits, is the starting point and foundation of any learning process. Neuroscience can serve as a foundation for education in the same way that biology serves as a foundation for medicine, meaning that each field retains its creativity but cannot violate the laws of the other. This work examines the relationship between neuroscience and educational practice, focusing on how teachers and school psychologists can use potential research findings from these fields to bridge the gap between them.

Keywords. Educational Neuroscience, Academic Environment, Neuroeducation, Psychology, Learning, Cognition

1. Introduction

In recent decades, educational neuroscience research and practice have expanded. Due to the difficulties of incorporating neuroscience data into educational practice, there have been calls for educational psychology to act as a link between the two disciplines (Mason, 2009; Craig et al., 2020). Educational psychology encompasses areas related to educational systems and practices: prevention, assessment, intervention, and progress monitoring; fundamental neuroscience and research knowledge, as well as a solid basis for higher cognitive functions (perception, attention, memory, concentration, etc.). In addition, school psychologists' use of counseling as a practice and the concurrent implementation of digital training and lifelong learning programs for teachers can help bridge the gap between neuroscience and education (Guli, 2005). Despite this skill set and appeal, educational psychology and school psychology are underrepresented in educational neuroscience research and practice. This article discusses how educators and school psychologists can bridge the gap between neuroscience research and educational practice by incorporating neuroscience into educational practice.

2. Literature Review

Although educational neuroscience was introduced more than three decades ago, some have argued that it is inapplicable to education. Since the initial assertion that the gap between neuroscience and education was insurmountable, it has been recognized that psychology can serve as the link between the two fields. Researchers in education use neuroscience to comprehend behavioral data (Howard-Jones et al., 2016). Several aspects of neuroscience have influenced educational practice. For instance, neuroscience has referred to a variety of neural mechanisms associated with specific learning difficulties, such as dyslexia, and highlighted therapeutic interventions to treat them. The significance of emotional parameters (anxiety, anger, etc.) has also been emphasized. as well as the function of physiological functions (sleep and rest) in learning performance.

There are well-established barriers to applying neuroscientific research to education. Theoretical obstacles include the two disciplines' fundamentally different research goals and scales (neurons firing at the millisecond level versus conceptually shifting the level from minutes to hours). To demonstrate this incompatibility, it is worthwhile to inquire "what constitutes best practice in each discipline?" While there is no definitive answer to this question, one can imagine a scenario in which the best teaching practices include moment-to-moment adaptations and responses to the immediate environment and the instructional needs of students. Moreover, neuroscience can support education similarly to how biology supports medicine, indicating that each field retains its originality. Nonetheless, it cannot violate the law of the other domain (Churches et al., 2020). This analogy is based on the fact that neuroscience is a natural science whose objective is to study the functions of the brain, just as biology investigates the functions of the human body. In contrast, education seeks to develop pedagogies, and thus has more in common with the way medicine uses biology to ground research and practice in therapies and the way architecture uses physics.

It is more likely that school districts located near universities with school or educational psychology programs will have opportunities to collaborate on educational neuroscience application to practice research. Ineffective implementation of educational neuroscience in schools is also hindered by a lack of support from administration and teachers, limited training and technical support in implementing new practices, economics, and divergent philosophical perspectives, particularly regarding research.

The scope of educational psychology is restricted to research. Consequently, educational psychologists typically work in academic and research settings. School psychologists are involved in the practice, typically supporting the academic and social-emotional development of students and assisting teachers in school districts. The application of neuroscience in educational practice may be supported by data-driven decision making, academic interventions, and school-wide learning-promoting educational supports and practices. In addition, school psychologists may play a significant role in the development of academic interventions and instructional practices to improve student learning and outcomes in crucial subject areas such as reading and mathematics. Educational neuroscience training imparts key findings that can be used to inform the development and improvement of interventions and practices, thereby increasing the likelihood that they will demonstrate efficacy in rigorous pre-implementation testing, such as randomized controlled trials. Unlike their non-dyslexic peers, children with dyslexia fail to activate the dorsal prefrontal cortex during phonological awareness tasks (Kovelman et al., 2012). This finding suggests that interventions targeting executive functioning and phonological awareness may be more effective than

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interventions targeting phonological awareness alone in improving reading outcomes among dyslexic children.

Similarly, developmental dyscalculia is associated with weaker functional activation in the right intraparietal sulcus, insula, and inferior frontal lobe during a spatial working memory task, as well as a diminished working memory capacity. This finding suggests the importance of targeting spatial working memory in math interventions for dyscalculic children (Rotzer et al., 2009). In fact, convergent evidence from the fields of neuroscience and psychology demonstrates strong and dependable associations between spatial and mathematical processing. This provides additional evidence that different levels of analysis (brain and behavior) can lead to a deeper understanding of academic achievement in a particular domain (e.g., mathematics) and the mechanisms that may underlie successful interventions (Hawes & Ansari, 2020). Recently, researchers have utilized this knowledge base to design laboratory and classroom instructional interventions to improve students' visuospatial skills and math performance (Lowrie et al., 2017).

Due to their training in both research and practice, school psychologists are in the best position to assist principals and teachers in making evidence-based decisions regarding which interventions to implement, challenge, and avoid. School psychologists are well-equipped to translate neuroscientific knowledge into evidence-based academic interventions and instructional practices that can be implemented to close the achievement gap between low and high achievers. The response of students to each level of intervention, as measured by curriculum-based assessments, determines whether they require the next level of intervention. School psychologists are frequently involved in all the aforementioned steps, including assessment administration and interpretation, intervention development and implementation (Fletcher & Vaughn, 2009).

Neuroeducation and Academic Capabilities

Neuroeducation can increase students' basic abilities in the educational process, as demonstrated by the intervention programs in the three schools, where reading, math ability, and empathy all improved significantly. This conclusion was reached following the conclusion of program implementation, when the results for each student from the beginning to the end of the intervention were compared. According to Caballero and Llorente (2022), these findings support the inclusion of neuroeducation in the classroom and confirm the efficacy of incorporating neuroscience into teacher education as a preliminary step toward enhancing students' fundamental skills.

Neuroscientists also, are redefining academic leadership in the twenty-first century by imbuing the neurological foundation and neural basis of leadership effectiveness with new significance for leading oneself, others, and an organization with a triple focus on effectiveness. According to neuroleadership educators, mastering the neuroscience of social behavior for engagement, motivation, and peak performance is necessary to comprehend the neurological foundations of educational leadership success (Antonopoulou et al., 2020; 2019). To address the difficulties of lowering performance disparities and adjusting to changing populations, the leader of the 21st century must also possess neuro-leadership skills to build relationships, regulate emotions, make decisions, and motivate employees or educators to reach company or educational institutions' objectives accordingly (Halkiopoulos et al., 2022). According to the researchers (Antonopoulou et al., 2021a;2021b; 2021c) the recorded knowledge of brain patterns has minimal influence on current social behaviour. Neuroimaging research has shown similar outcomes, demonstrating that incorporating neuroscience insights into educational

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leadership will not alter management paradigms, i.e. In contrast, neuroscience has offered a challenge to organizational management and given organizational and leadership performance a new meaning (Halkiopoulos et al., 2020). Neuroscientific data may be important in defining educational leadership in terms of cognition, particularly in terms of academic leaders' decision-making, problem-solving, emotional control, and personal traits (Gkintoni et al., 2022a).

Additionally, improving empathy as part of social, emotional, and moral competencies raises new questions that require further investigation (Llorent et al., 2020). According to Arwood & Merideth (2017), the development of executive functions and self-regulation skills may be more closely associated with greater gains in reading, mathematics, and empathy. This may indicate the need for explicit social and emotional development of the aforementioned three competencies. Current research indicates that a method based on cooperative learning would be more effective for developing social and emotional competencies (Llorent et al., 2022). However, the increase in empathy in both experimental groups suggests that executive functions may have impacted the student's ability to regulate behavior and cognition through adequate inhibitory control. It can also lead to the conclusion that cognitive flexibility, which facilitates the regulation of reading and reasoning processes via metacognitive skills, can significantly impact social and emotional abilities such as empathy and facilitating social interactions (Caballero & Llorente, 2022). Based on research findings (Gkintoni et al., 2021c; Gkintoni & Dimakos, 2022) these hypotheses suggest the importance of developing all abilities from a neurological perspective and highlight the impact of executive functions and metacognitive processes on the development of essential academic abilities.

Reading has seen the most significant neuroeducational advancements in general. According to Ansari et al. (2011), cognitive neuroscience research has demonstrated how brain circuits are disrupted in children with dyslexia and identified a set of brain regions whose activation patterns respond differently during basic reading tasks (e.g., similar endings, reading single words). A growing number of recent studies have investigated the effects of structured reading remediation programs on the brain function of students with dyslexia, leading to the conclusion that these interventions alter the functional patterns of brain activation associated with reading. These findings suggest that neuroscience-based instruction leads to the development of new reading strategies in individuals with dyslexia and encourage further investigation into the precise methods by which they can compensate for their difficulties. Research on the neural circuits underlying math skills lags behind research on reading abilities. Researchers have gained a better understanding of the formal and informal development of mathematical skills as a result of the identification of brain regions essential to the representation and processing of numerical processes. What is lacking in the neuroscience of mathematics are studies examining the brain activity of children who are learning mathematics and how this activity is affected by different educational conditions. In addition, studies evaluating the effects of structured remedial interventions on brain function in students with math difficulties (e.g., dyscalculia) are urgently required (Ansari et al., 2011). Emerging in the context of neuroscientific research revealing plastic changes in the brain following learning is the question of whether training specific cognitive functions can result in enhancements to overall brain function.

According to Ansari et al. (2011), working memory, a limited-capacity mechanism that allows us to hold and manipulate information during continuous task performance, has received considerable attention as a neurocognitive function (Gkintoni et al., 2017). This skill is essential for success in learning-related domains such as reading, language acquisition, and mathematics. Therefore, training the working memory can enhance performance in these academic disciplines. Studies have demonstrated that working memory training increases activation in frontoparietal brain regions and alters performance, not only on tasks that participants were trained to perform but also on untrained working memory tasks (Gkintoni et al., 2022b).

3. Methodology

This paper presents a precise critical literature review with an emphasis on educational neuroscience, a relatively new scientific field with a variety of theories, methods, and techniques as applied and updated in educational research and practice. The following research questions will be examined in this work:

- [RQ1] How can we theoretically and philosophically approach education using Educational Neuroscience?
- [RQ2] How are Educational Neuroscience's motivations, methods, and influences interpreted?
- [RQ3] What is the connection between educational neuroscience and the process of learning?
- [RQ4] What role does school psychology play in bridging the divide between educational neuroscience and educational practice?
- [RQ5] What contributions can educational neuroscience make to the teaching of mathematics?

The research literature was culled from databases such as Google Scholar, Eric, SCOPUS, and ScienceDirect, using keywords like “neuroscience and teaching” and “neuroeducation”.

4. Results

As mentioned previously, one way to move forward is to take a cue from the relationship between biology and medicine, which has faced similar challenges as neuroscience and education. Similarly, to how medical practice is not a biological experiment, classrooms are not testing grounds for neuroscience. Moreover, due to the vast diversity of students and teachers, extensive replication of the research is required to account for individual differences and establish effectiveness over efficiency. As a result, it is necessary to conduct real-world experiments that incorporate key differences in educational systems and environments, similar to how physicians publish their findings. Infrequently do teachers, with the assistance of school psychologists, actively participate in the research for the latter.

Moreover, it is essential to foster collaborations between academic school psychology and neuroscience educational programs. To facilitate collaborative research and the incorporation of research findings into curricula, pedagogical practices, and interventions, cooperating programs may wish to jointly appoint a liaison between their researchers and school personnel. In addition, such programs could consider establishing outreach programs in which researchers in school psychology and educational neuroscience meet regularly with school personnel, with school psychologists serving as the primary school liaisons. Ph.D. students in school psychology would be ideal candidates for research in this program, as they are required to conduct research as part of their degree. Moreover, because of their training, they are frequently interested in applied research. This type of collaboration would be mutually beneficial because it would involve schools in research, including the formulation of research questions (Churches et al., 2020; Thomas et al., 2019).

Such programs will enable researchers to communicate their key findings to school personnel, with an emphasis on how they can be used to enhance learning and foster staff collaboration. In addition to this staff-focused approach, school psychology and educational neuroscience researchers could provide periodic outreach within schools where they teach both teachers and students about the brain and learning, as well as provide opportunities for interested students and teachers to participate in research in schools or laboratories. School psychologists are in a position to help coordinate these outreach activities and could serve as mediators between school staff and academic school psychologists and educational neuroscience researchers. Such networking and outreach programs will facilitate the development of strong relationships between academic school psychology and educational neuroscience researchers and school personnel, which are required for collaborative translational research to the mutual advantage of both parties.

5. Discussion

Whether Educational Neuroscience can contribute to classroom practices is an unanswered question. Critics argue that there is no direct connection and that research proposals must be thoroughly evaluated. However, understanding fundamental neuroscience research on learning and its underlying components is equally as important as studying child development, educational psychology, or any other aspect of teacher education. Educators must keep abreast of what scientific research has taught us about the brain, emotions, motivation, and physiology, just as physicians and psychologists must attend professional development workshops to stay current. Through students' comprehension and capacity to create and implement more effective subject units, this information can benefit classroom practices.

Educators and educational theorists proposed several the practices validated and supported by neuroscience long before neuroscience validated and explained their meaning. Educational Neuroscience can provide us with new strategies and suggest that, considering better information, some of our current strategies should be eliminated (Kauffman et al., 2008). In addition, recent brain imaging studies have demonstrated that numerous mental processes underlie the school-assigned tasks.

Neuroimaging studies have revealed the complexity of brain region interactions and the existence of multiple learning pathways. An educational neuroscientist can advise teachers against self-diagnosis and assist them in designing lessons with multiple understanding and practice pathways that provide options for diverse and struggling students.

In contrast to the distinctions made by learning styles theory between visual, auditory, and kinesthetic learning, neuroscience research has demonstrated the importance of vision in learning (Gkintoni et al., 2021a). All components of a lesson utilize brain resources and increase cognitive load, so images must be meaningful and contribute to the lesson (Antonopoulou et al., 2022; Antonopoulou et al., 2021; Giannoulis et al., 2022). This type of scholarly literature synthesis requires knowledge of both the body of literature and the types of learning opportunities educators design to enhance lesson planning.

Challenges and Limitations

While this research progress is encouraging, the emerging field of Neuroeducation faces numerous obstacles. According to Ansari et al. (2011), we must consider the following four ethical issues: inter-disciplinary communication, the status of biological explanations of behavior, managing expectations across disciplines, and methodological limitations.

The differences in understanding between educational researchers, teachers, and neuroscientists regarding the disciplines, practices, and methodologies each use is one of the greatest obstacles to Neuroeducation. This communication breakdown can result in fundamental misrepresentations on both sides (e.g., neuromyths). The assumption that a biological explanation of behavior is more trustworthy than a non-biological interpretation is also a form of bias that can be eradicated through proper teacher training. As previously stated, it is crucial to understand that the human brain exhibits remarkable plasticity and is shaped by experience. Neuroeducation faces a challenge in overcoming the limitations placed on educational research by currently available neuroscientific methods. Increasing the samples used in research is also a challenge, as many current studies lack adequate control groups or have not examined the effects of training on different populations, age groups, etc. (Ansari et al., 2011).

For researchers and educators to effectively address Neuroeducation issues, interdisciplinary training is necessary. This implies that we must, on the one hand, create opportunities for neuroscientists to engage with education and, on the other hand, train teachers to equip them with an understanding of key concepts in neuroscience, brain development, brain structures, and its learning-related functions.

Children with learning disabilities who struggle to advance in the standard curriculum have benefited from educational neuroscience research. The findings have proven useful for constructing valid and reliable learning theories for all students. Therefore, the design, implementation, and evaluation of interventions based on interdisciplinary collaboration continue to serve as a crucial link between neuroscience and educational practice (Jamaludin et al., 2019). The current state of "brain education" research demonstrates the need to incorporate neuroscientists and educators as equal "partners" in "neuroeducation" research.

6. Conclusion

Education is concerned with enhancing learning, whereas neuroscience seeks to comprehend the mental processes underlying learning. This common ground suggests that science will transform educational practice in the future, just as it transformed medical practice nearly a century ago. This article examined some of the essential neuroscience discoveries that could eventually lead to such a transformation.

It has been criticized that educational neuroscience has little impact on educational practice. This chasm is largely attributable to the lack of specific mechanisms that bridge neuroscience and education. This article argues that school psychologists can help bridge the gap between neuroscience and education. Educational and school psychologists are bilingual in order to comprehend the fundamentals of neuroscience and education, as well as the psychological concepts associated with both. In educational neuroscience, school psychology has not yet played a prominent role. As a research and practice field, school psychology possesses the knowledge, skill set, and vantage point to effectively contribute to bridging the gap between education and neuroscience. Therefore, school psychology has the potential to increase bidirectional collaboration between these fields, thereby enhancing teachers' access to accurate information and, consequently, student outcomes.

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