NSOU-OPEN JOURNAL ISSN: 2581-5415
Vol.9 No.1 (January 2026)
A Multidisciplinary Online Journal of Netaji Subhas Open University, INDIA

Harnessing Neuroeducation to Elevate Students' Academic Performance

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Abstract

Neuroeducation is an emerging interdisciplinary field focused on enhancing student learning outcomes by integrating insights from neuroscience concerning brain's learning potential into educational practices. The study explores the implications of neuroeducation for improving students' performance. Learning achievements are influenced by various factors, including individual traits like cognitive skills and external elements such as curriculum design. Neuroscience research highlights the differences in cognitive and emotional abilities among individuals, linking these differences to specific brain regions, which in turn affects their learning potential. This neurobiological approach has paved the way for neuroeducation, facilitating a shift from traditional educational methods to those informed by neuroscience-based curricula and policies. While the neuroeducation model shows promise in improving student performance in subjects like mathematics and reading, its effectiveness may be hindered by educators' understanding and application of neuroeducational principles. Therefore, further research is necessary to validate the impact of neuroeducation on student learning outcomes. As this field evolves and the application of laboratory findings to educational settings progresses, several recommendations are proposed to support the integration of neuroeducation into learning environments and address emerging challenges.

Keywords: *Learning outcomes, Memory, Neuroscience, Neuroeducation, Teaching*

Introduction

Neuroeducation is a vibrant and evolving field that connects neuroscience with education. Neuroscience focuses on the brain and its cognitive functions, while education emphasizes teaching and learning strategies. **Carew and Magsamen (2010)** characterized neuroeducation as a developing area that combines neuroscience, cognitive science, psychology, and education. **Howard-Jones (2016)** further describes neuroeducation as an interdisciplinary area integrating neuroscience, cognition, biology, psychology, and education. These insights provide a biological framework for comprehending learning and encourage policymakers to adopt this viewpoint when developing useful teaching methods, policies of education, and curricula. The term 'neuroeducation' is frequently used interchangeably with educational neuroscience and brain-based learning

Neuroscience is intricately associated with education through both direct and indirect pathways. Indirectly, it relates to education by means of psychological factors such as working memory and attention. Direct connections involve non-psychological aspects, including energy supply, nutrition, and air quality, which affect brain function and, consequently, learning processes. The core principle of neuroeducation is rooted in the brain's ability to perform essential functions—such as memory, emotional regulation, and problem-solving—that are vital for learning. Essentially, the brain synthesizes meaningful learning experiences through its various functions. Neuroscientific research primarily aims to elucidate the mechanisms of learning and the differences in learning abilities among individuals. This developing field is being utilized not only to assess individual learning potential and devise innovative educational strategies but also to inform science-based educational policies aimed at enhancing learning.

From an early age, the human brain undergoes continuous development, acquiring skills while also being susceptible to various influences. In the learning context, both emotional and cognitive stimuli play crucial roles in how the brain processes information, and these stimuli can vary significantly among individuals. The brain manages numerous functions, including goal-setting, decision-making, cognition, memory, problem-solving, rule adherence, and gratification. However, neuroscientists particularly highlight three key functions during the learning procedure: cognitive flexibility, working memory, and inhibitory control. These functions are often compared to the brain's air traffic control system. Working memory refers to the ability to grasp and manipulate information as needed, such as when following instructions. Cognitive flexibility involves the capacity to manage multiple tasks, switch between them, adapt to new ideas or rules, and maintain consistent attention. Inhibitory control encompasses evaluating potential outcomes of actions, regulating impulses, and engaging in planning. Neuroeducation also addresses various psychological factors, including cognition, attention, emotions, memory, motivation, social behavior, and neurodiversity. These issues are vital, as the brain develops at different rates among individuals, affecting their readiness to learn.

Globally, education has largely adhered to traditional principles that emphasize sitting, observing, listening, and writing. This cognitive-centric approach often neglects the integration of body and mind, failing to account for the unique differences among learners. Consequently, this has led to poor academic achievement, diminished novelty, insufficient creative thinking, and higher rates of failure and dropouts, highlighting the limitations of conventional education systems. In response, there has been a growing scholarly interest in neuroeducation, which aims to address the gap in brain-based learning and relate this understanding within educational scenario to enhance cognitive processes related to thinking and learning in children. The integration of neuroscience findings into education is mainly informed by scientific studies that illustrate how specific brain circuits and neurotransmitters are linked with different types of information. Some academicians and researchers have linked neuroscience to the activation of the hippocampus, areas crucial for learning and memory. Neuroimaging studies have also revealed complex interactions among various brain regions, suggesting the potential for multiple learning strategies tailored to diverse learners.

Thus, neuroeducation takes into account both cognitive and emotional aspects of the learning process, emphasizing the dynamics of teaching and learning at the neurological level. While further scientific evidence may be needed to solidify the connection between brain function and learning abilities, educators are particularly interested in exploring how neuroeducation can enhance the teaching-learning process and improve student outcomes.

Neuroeducation and Academic Performance: Researchers emphasize that the human brain has a natural capacity for learning that transcends formal education. As people age, their ability to acquire new knowledge and improve cognitive functions persists, driven by the activation of three crucial brain regions linked to motor skills, memory, and cognitive reasoning. Simultaneously, shifts in brain activity highlight a reciprocal relationship between neuroscience and educational practices. Education prioritizes academic success, which encompasses knowledge, understanding, and performance following a learning experience. Various factors influence these outcomes, including personal traits, school environments, societal influences, family dynamics, and government policies. The main objective of neuroeducation is to improve educational results by addressing these factors, particularly by modifying proximal elements such as health, nutrition, attention, motivation, and ability, along with school-related aspects like teaching materials, teacher skills, classroom environments, and institutional policies.

Since the 2009 Neuro-Educational Summit, the field of neuroeducation has grown significantly. Neuroscience research has identified the spacing effect, which indicates that breaking information into smaller, manageable segments enhances retention and understanding. Additionally, the use of visual aids and interactive assessments promotes higher-order thinking skills. As a result, educators and researchers are investigating neuroeducation as a means to improve training outcomes, particularly in reading, numeracy, and mathematics. Neuroscience indicates that effective learning depends on neuronal activation and connectivity, suggesting that traditional classroom instruction may not always be conducive to learning. Moreover, individual differences can create diverse learning pathways. Neuroscientists contend that teaching and learning are fundamentally biological processes, implying that neither the child nor the educator can be solely held responsible for poor educational outcomes. Schools act as educational centers for children, providing emotional support and implementing effective learning strategies based on neurocognitive principles, thereby laying a strong foundation for students' academic and professional growth.

Recently, many educational programs have incorporated neuroeducation into their curriculum to attract parents and boost their business prospects. Despite advancements in neuroeducation over the past decade, only a few studies have explored its application within existing educational frameworks and its potential impact on student learning outcomes. Research utilizing brain-based strategies to teach science to seventh graders showed improvements in their self-esteem and academic performance. Additionally, the use of brief audio-visual presentations in classrooms increased university students' attention and emotional engagement, indicating that significant materials with audio-visual elements can enhance readiness. A similar positive effect of neuroeducation was observed in the identity development of adult learners. Visual learning strategies have been beneficial for the social and cognitive growth of K-12 students. Research found that, despite teachers' limited knowledge of neuroeducation, fifth graders demonstrated improved academic performance. The application of neuroscientific insights, such as the brain's reward system, in a game-based educational tool called Zondle Team Play (zTP) showcased the method's practicality and effectiveness, with students displaying enthusiasm, emotional engagement, and better communication with their teachers.

During the COVID-19 pandemic, **Espino-Díaz et al.** (2020) highlighted the benefits of integrating Information and Communication Technology (ICT) with neuroeducation in the educational framework. With schools closing, there was a significant shift from traditional classroom teaching to online learning, confining both educators and students to their homes. This transition also led to increased social anxiety, health-related stress, depression, and other challenges arising from these unprecedented circumstances. In this context, the authors propose that the neuroeducation framework may aid in emotional regulation and boost student motivation. The relevance of the neuroeducation framework spans various domains, including reading skills, language acquisition, scientific understanding, mathematical abilities, and developmental disorders.

Reading Competence: A specific study found that schools across the United States implemented programs like Brain Gym, which feature short psychomotor activities aimed at enhancing learning and improving reading skills among fourth-grade students. This research demonstrated a link between physical activity and increased electrical activity in the hippocampus, leading to better learning outcomes and improved long-term memory retention. In addition, a case study was conducted at an early childhood education center in Gurgaon, India, utilizing the Brain-Targeted Teaching (BTT) model. This initiative focused on enhancing both the emotional climate and the physical environment to create a more effective learning experience. The use of theme boards decorated with vibrant images and icons was identified as beneficial for advancing students' reading skills. The collective experiences of teachers and their application of BTT strategies were pivotal to the successful implementation of the BTT model within the early childhood program.

Language: Language is essential for literacy and cognitive development. Murphy's (2017) narrative inquiry integrates visual strategies and informal evaluations, which were found to be very effective. This model, centered on neuroeducation and its application to writing instruction, resulted in considerable improvements in language skills among kindergarten students, particularly following an 8-week intervention aimed at enhancing both speaking and writing.

Science and Mathematics: The utilization of neuroeducation techniques has resulted in significant enhancements in concentration, memory, reading proficiency, and mathematical skills among school children from economically disadvantaged backgrounds that face social issues such as violence and substance abuse. Although scientific evidence regarding the precise mechanisms of neuroeducation remains limited, researchers continue to express optimism about its potential to bridge the gaps in reading and mathematics skills for young learners. Research employing neuroimaging has linked mathematical proficiency in both children and adults to specific regions of the brain.

In comparison, Brain-based Learning has demonstrated greater effectiveness than Project-based Learning in improving students' performance in mathematics, indicating that insights derived from neuroscience can greatly assist in developing age-appropriate curriculum that correspond with learners' cognitive capabilities. In a neuroeducation study, students underwent MRI scans before and after engaging in Modeling Instruction (MI) in introductory physics. The results indicated increased brain activity in the lateral prefrontal and parietal cortices, which correlated with improved performance in physical reasoning tasks. These brain regions, known as the central administrative network, are linked to attention, working memory and problem-solving skills. By incorporating neuroeducation principles, **Zhang (2019)** developed a curriculum and instructional strategy for an advanced computer programming course. This innovative approach enhanced the learning experience by shifting away from traditional linear teaching methods, reorganizing chapter sequences, and linking new information to prior knowledge. This strategy allowed for quicker knowledge acquisition by enabling students to leverage earlier cognitive experiences. Consequently, there was a marked improvement in computational thinking skills as cognitive psychology and physiology were woven into the educational framework.

The impact of neuroeducation on students with special needs is significant and transformative. Studies have delved into neuroeducation strategies specifically designed for children facing speech or language challenges. Notably, integrating these strategies with Neurosemantic Language Learning Theory (NLLT) has been shown to enhance the clarity and language abilities of children at risk of Childhood Apraxia of Speech (sCAS). Additionally, research indicates that students with emotional and behavioral disorders (EBD) and language impairments have demonstrated improved pro-social behaviors through neuroeducational methods. These findings underscore the intricate relationship between cognitive psychology, neuroscience, and language, all framed within the neuroeducational approach pioneered by Arwood. Numerous studies discussed here offer compelling evidence that neuroeducation positively influences students' academic performance. As research in neuroscience advances, our understanding of the brain's role in learning becomes clearer. Certain studies have pinpointed specific brain regions associated with cognitive functions, suggesting that tailored curricula and teaching strategies can enhance brain activity and lead to better educational outcomes.

It's essential, therefore, to transition from outdated teaching practices to those informed by contemporary neuroscience. This involves updating curricula and instructional techniques to design effective learning experiences that resonate with students. In essence, neuroeducation plays a crucial role in nurturing foundational learning while taking into account the cognitive and emotional characteristics or mental health needs of each student. For educators, the ability to weave neuroscience into their teaching practices is invaluable. Neuroeducation is an emerging field that has proven to positively impact student learning. However, the effectiveness of neuroeducation in enhancing learning achievements largely hinges on the teaching methods employed by educators, emphasizing the vital role teachers play in this process. A qualitative study conducted by Shepherd examined various key factors, including students' prior knowledge, reinforcement techniques, and emotional aspects. Findings indicated that many middle school teachers often do not fully understand neuroeducational strategies or the connection between cognitive processes and emotional responses. This lack of understanding can hinder the successful integration of neuroeducation into teaching practices.

Similarly, **Murphy (2017)** highlighted several challenges in implementing neuroeducation, such as low self-efficacy, hesitance, and conflicting mindsets among educators. A parallel lack of awareness regarding neuroeducational pedagogy was noted among instructors in adult education settings. On a more positive note, a mixed-methods study involving teachers of the United States pointed out the critical need for understanding brain functions to identify learning difficulties and tailor support for students with special educational needs, which can be cognitive, physical, behavioral, or emotional in nature. The research suggested that neuroeducation has the potential to significantly enhance the design and execution of educational programs. While educators in the United States expressed enthusiasm regarding neuroeducation, they indicated that direct engagement with neuroscientists was not a necessity, as they generally depended on secondary resources such as books and conference materials for their information. The teachers underscored the significance of having neuroeducational resources that are readily accessible, emphasizing their importance within the classroom environment.

Hook and Farah (2013) recently carried out interviews with educators who participated in the 'Learning and the Brain' conferences. They identified three key themes that are vital for teachers: their motivations, the impact on classroom practices, and the concrete benefits derived from this experience. Educators were mainly driven by a wish to investigate innovative teaching strategies, engage in intellectual discourse, and broaden their understanding across various disciplines. These areas included comprehending how the brain operates in an educational framework, integrating neuroscience with teaching methodologies, and adopting a comprehensive educational approach that encompasses brain function.

A significant focus was placed on how neuroeducation can be practically applied in teaching and across different subjects. While the effects on classroom practices varied, most educators reported increased student engagement, a stronger commitment from both teachers and students, and improved lesson planning. They also experienced practical benefits such as boosted authority in the classroom, better management of challenging students, greater professional satisfaction, and an improved self-image. Teachers adopted various strategies, including redesigning the classroom layout, reorganizing lessons, and using graphic organizers, showcasing an effective neuroeducational approach.

Recognizing the need for effective neuroeducational training, **Compagno and Pedone (2016)** developed a micro-planning activity tailored for teacher training, grounded in the Theory of Multiple Intelligences. This training equipped educators to utilize cognitive and intellectual frameworks to create structured, neuro-focused teaching methodologies. As a result, teachers were empowered to foster meaningful communication and engagement with their students. Recognizing the scarcity of empirical research on the integration of neuroscience in education, **Luzzato and Rusu (2019)** developed a questionnaire for a pilot study aimed at evaluating the self-efficacy and attitudes of Israeli teachers engaged in neuroeducation. Their results revealed that psychosocial factors, such as self-efficacy and attitudes, can facilitate positive changes in teaching practices. While Israeli pre-service teachers demonstrated an optimistic perspective and a readiness to incorporate neuroeducation into their classrooms, their relatively low self-efficacy pointed to knowledge gaps. Existing literature indicates that enhancing teachers' understanding of brain development and offering neuroeducation training can significantly improve their interactions with students.

Barriers of Neuroeducation: The primary objective of educational neuroscience, often referred to as neuroeducation, is to improve the brain's ability to learn by altering the learning environment. This methodology utilizes knowledge from multiple disciplines, such as cognitive psychology, neuroscience, and education, to create effective teaching strategies, interventions, curricula, and educational policies. However, the integration of neuroscience into education remains uncertain. While both scientists and parents generally view brain-based teaching favorably, current literature reveals limited implementation of neuroscience in educational practices, highlighting challenges at multiple levels. A major concern among educators is their lack of knowledge and awareness regarding neuroscientific research. Many educators emphasize the need for practical applications and the effectiveness of neuroeducation in their teaching.

Additionally, there is a widespread misconception among the public that neuroeducation primarily aims to debunk common neuromyths, such as the idea of limited brain usage or gender biases. Research by Thomas et al. indicates that understanding learning through the brain is a complex and evolving process. Yet, society often prioritizes traditional classroom learning, which can obscure clarity in educational contexts. This focus presents significant challenges for researchers and educators trying to implement brain-based learning principles in practical settings, curriculum development, and teaching methodologies.

Moreover, scholars and researchers have been advocating for the reliability and effectiveness of curricula that incorporate neuroeducation. There is an urgent need for more evidence to validate the effectiveness of brain research, as its application in classroom instruction remains a pressing concern. Ultimately, as neurologist Judy Willis points out, it is crucial to connect scientific discoveries in neuroeducation with their practical effectiveness in educational environments.

Conclusion

To effectively incorporate neuroeducation into classroom instruction, it is crucial to reform both educational policies and practices. The focus should shift from standardized testing and rigid curricula to recognizing the unique cognitive strengths of each student. While understanding scientific research related to neuroimaging and neuroscience is advantageous, it is vital to apply these insights in practical, real-world educational settings. This includes addressing the significance, limitations, and practical implications of neuroscience in education. This review highlights several key points based on the recommendations of researchers. Policymakers on education must stay receptive to emerging research findings, acknowledge the diverse cognitive and emotional abilities of children, and conduct thorough assessments prior to modifying current policies and practices. Educational strategies should be developed with an understanding of psychological factors to improve student learning outcomes. It is crucial for universities to employ qualified educators and faculty members who have a comprehensive grasp of neuroscience and psychology. Teacher training programs should include education-related neuroscience and cognitive science training, ensuring that these opportunities are available to all educators, including those who assist students with Special Educational Needs.

Additionally, the hiring of neuroeducational engineers will encourage teachers to explore alternative teaching methods. Students should also be encouraged to participate in neuroscience training. Any effective teaching approach must be based on reliable research. In this regard, educational materials and resources should avoid using brain-based terminology solely for the purpose of boosting sales. Furthermore, a 'bench-to-bedside' approach is crucial in the field of neuroeducation. It is essential for scientific researchers to connect neuroimaging discoveries with practical applications in educational environments. The collaboration and sharing of knowledge between neuroscientists and educators will help identify the real challenges faced by teachers and allow researchers to tackle these issues in their laboratory studies. With the rapid development of information and communication technology (ICT), neuroeducation can be incorporated into the educational framework. Highlighting adaptive learning technologies that foster personalized learning is essential for supporting individuals, irrespective of their abilities.

For centuries, neuroscientists have been fascinated by the intricacies of the human brain. Although significant progress has been achieved in comprehending specific brain functions—such as the connections between neural regions and aspects like cognition, emotion, and motivation—much remains to be uncovered. The link between neuroscience and education was recognized long ago, yet it has only recently started to gain momentum. The use of neuroscience in educational settings is still ambiguous due to the difficulties in translating scientific findings into effective teaching methods. Nonetheless, ongoing studies are investigating the beneficial effects of neuroeducational strategies on student learning outcomes. Consequently, it is crucial for educators and policymakers to understand both the potential and limitations of neuroscience research and to develop innovative strategies that improve student learning.

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