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Systematic Review

Neurobiological foundations of learning: a systematic review of efficacy of brain-based learning strategies for learning disabilities

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ABSTRACT

Learning disabilities hinder brain development, resulting in impairments in the capacity to develop learning capabilities. Education involved in developing the brain and learning capabilities, that helps to manage learning disabilities. For this, teachers should have the potential to integrate neuroscience in general classrooms. Brain-based learning provides the foundation that integrates classroom practices with the neurological findings. This paper systematically reviews the efficacy of brain-based learning strategies in managing learning disabilities. This systematic review aims at identifying articles which include the brain-based learning strategies interventions that enhance the learning capabilities in the learners with learning disabilities. For this, academic intervention based on neuropedagogy, termed "brain-based learning strategies", "brain-based instructions", and "brain-compatible teaching", along with the learning disability which is termed "learning disabilities", "learning disorders", "dyslexia", and "dyscalculia", are being reviewed. For this systematic review, four databases (PubMed, Taylor & Francis, ScienceDirect, and ERIC) were used. After including the MeSH of PubMed and the Thesaurus of ERIC, two reviewers independently reviewed and sought out four out of the 438 studies that align with the inclusion criteria. This systematic review indicates that when brain-based interventions are provided to the learners in the terms of strategies such as multisensory instructional techniques, constructivism teaching, orchestrated immersion, relaxed alertness and active processing, can bring out the development of various learning capabilities as improves the functions of mind, improving study habits and relieving test anxiety and improve the mathematical skills and scientific thinking in learners with learning disabilities.

Keywords: Brain-based learning, Brain-based learning strategies, Neurobiological foundations, Learning disability

INTRODUCTION

Learning is a crucial aspect of children's lives, where they acquire new things, languages, and skills from an early age. NCFSE, 2023, advocated that the brain plays a vital role in learning, as it is made up of ever-changing connections between millions of neurones.[1] Various parts of the brain encompass numerous learning capabilities, such as the frontal lobe, the largest, located at the front of the head and responsible for high cognitive functions like decision-making, planning, problem-solving, and emotional control; the parietal lobe, located at the top and back of the frontal lobe, which accountable for sensory information like touch, temperature, and pain; and the temporal lobes, located at the side of the brain below the lateral fissure, involved in memory formation, regulation, and visual perception.[2-4]

The occipital lobe, which is at the back of the brain and is protected by the occipital bone, is dealing with processing visual information and understanding space.[5]

When differences in brain structure occur, they can lead to difficulties in learning, resulting in disabilities for students in specific tasks; this condition is referred to as a learning disability. UNICEF claims that in this world nearly 240 million children have disabilities, which means one in 10 learners is facing learning disabilities.[6]

Learning disabilities are neurological disorders that create hurdles in acquisition, organization, retention, comprehension, and so on.[7] According to types of disorders, these disabilities can be identified on the basis of differences in the brain structure; these differences create the difficulties in the specific functions For instance, a common difference in learning activities is the reduced activation in the left temporal, parietal, and fusiform regions of the brain, which causes phonetic problems leading to difficulties in reading and spelling, known as dyslexia.[8] Furthermore, when white and grey matter volume is reduced in brain regions like the parietal cortex, especially in the intra-parietal sulcus, additionally the frontal and temporal lobes, it could be the cause of the difficulties occurring in the calculative and numerical skills known as dyscalculia.[9]

Currently, with increased advocacy for inclusive education, diverse learners come together to facilitate the learning process, but the learners with special needs require special attention and also face various challenges that other students do not.[10] Schools and formal education play a vital role in creating an environment that supports brain development, which strengthens learning capabilities and skills.[11] The teacher's responsibility has increased to effectively support students with learning disabilities in managing their challenges within the learning environment.[12] To enhance learners' capabilities, teachers should understand the neurological differences associated with disabilities and identify which activities stimulate specific regions the brain, allowing them to minimize the effects of these disabilities and optimize learning outcomes.[13] For a regular teacher, it is difficult to grasp the neurological information; here a platform is needed that could integrate the neurology with education and align with the classroom environment and content.

The concept of brain-based learning has the potential to fulfill this gap, as brain-based learning uses neurological evidence and integrates it into the classroom. These strategies are brain-based learning approaches grounded in 12 principles that integrate neurology with education and align with the teaching content.[14]

The primary objective of this paper is to systematically review the effectiveness of brain-based learning strategies in addressing learning disabilities.

METHODS

Eligibility criteria

The following inclusion criteria are applied in the research: the research is based on that which addresses the learning disabilities and brain-based learning; only classroom-related study; the published studies used; and the studies must be published in the English educational language. The exclusion criteria of this paper are: grey literature (books, dissertations, conferences); studies with meta-analyses, systematic reviews, reviewal trials, cross-sectional studies, case studies, and cohort studies; and non-educational studies.

Information sources

This systematic review used four databases: PubMed, Taylor & Francis, ERIC, and ScienceDirect from 2016 till now, and 438 research papers were reviewed, from which only seven studies were matched with the inclusion criteria of this paper.

Search strategies

This paper utilized a mixture of keywords and Boolean operators, such as AND and OR, including “brain-based learning” OR “brain-compatible learning” OR “neuropedagogy” AND “learning disabilities” OR “learning disorders” OR “dyslexia” OR “dyscalculia”. Additionally, the MeSH advanced search in PubMed was also utilized, but no similar words were found.

Selection and data collection process

For the selection process, three reviewers worked independently and screened the titles and abstracts retrieved from the initial search. RAAYAN software was also utilized to remove the duplication of the searches of the PubMed Database, but no results were found in this for duplication. The data extracted for this research aligned with the inclusion criteria, while studies irrelevant to it were excluded. Disagreements among the reviewers were rectified through the discussion and consensus (Figure 1).

Data items

The data were selected from 2016 to 2025, published in English, and categorized according to the PICO framework (population, intervention, comparator, and outcome). In this paper, school students, including both males and females, were identified as brain-based learning strategies that should be utilized in the studies. The outcomes of the data were chosen for developing the learning capabilities in the learning-disabled students and managing the disability of the students.

RESULTS

Study selection

We selected the data for this paper from four databases: PubMed, Taylor & Francis, ERIC, and ScienceDirect. MeSH of PubMed and the Thesaurus of the ERIC database are also utilized for the search strategies. 270 results from ERIC, 93 results from ScienceDirect, 81 results from PubMed, and 4 results from Taylor & Francis were found that were reviewed and manually reviewed by the reviewers, and the Rayaan tool was used to remove the duplication and assess the alignment with the inclusion criteria of the found results. After filtering out, four studies were selected that align with the inclusion criteria.

Study characteristics

These four studies were selected that associated classroom-based intervention, students with learning disabilities, and brain-based learning strategies or brain-based learning instructions.

They were utilized in these studies (Table 1).

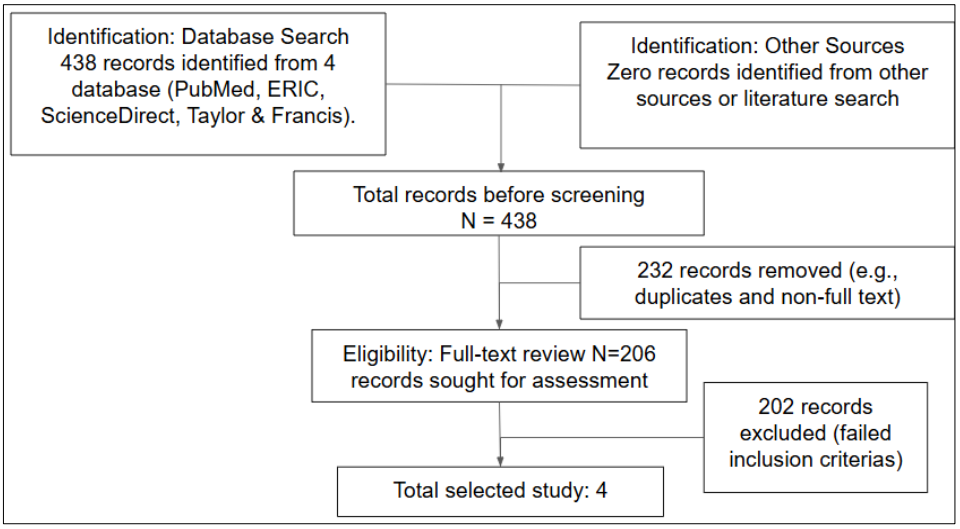

Figure 1: Methodology of the study.

Table 1: Characteristics of the studies that were included in brain-based learning/brain-compatible teaching and learners with learning disabilities.

Citation	Location	Study design	Sample size	Age	Intervention	Comparator	Terms for disability	Strategies
Ji et al[15]	China	Mixed factorial design	21 children with LD and 20 non-LD children	12-13 year male and female students	Stimuli and event-based on the PM paradigm	Non-disabled children	Learning disability (LD)	Color discrimination task, and category naming experiment
Rasheed and Hanafy[16]	Saudi Arabia	Quasi-experimental	20 students in treatment group 20 students in control group	Kindergarten students	Brain-based learning strategies (brain constructing learning process)	Control group	Children at risk for learning disabilities.	Multisensory instructional techniques, constructivist teaching
Nassar and Ahmed[17]	Egypt	Experimental	60 students	First-year preparatory school students	Brain-based learning approach	Control group	Students with learning disabilities	Orchestrated immersion, relaxed alertness', active processing
ElAdl[18]	Oman	Quasi-experimental design	71 students	Grade 7	Brain-based learning theory	Control group	Students with learning disabilities	Principles of BBL, principles of BCL

Intervention

This paper includes the studies that used the intervention brain-based learning, such as the intervention stimuli-constructing and the event-based PM paradigm.[15] brain-based learning strategies (brain-constructing learning process); the brain-based learning programme as the intervention-constructing treatment group; and the brain-based learning theory as the interventions.[16-18]

These interventions utilize the brain-based learning strategies that have the neurological basis that aligns with the teaching content and helps strengthen the learning capabilities of the students struggling with the learning disabilities. These strategies are the colour discrimination task, the category naming experiment, multisensory instructional techniques, constructivism teaching, orchestrated immersion, relaxed alertness and active processing, the principles of brain-based learning (BBL) and brain-compatible learning (BCL).[15-18]

Control group

These studies utilized control groups for comparators which did not receive any interventions; only one study utilized the control group as the non-disabled children.

Outcomes

These reviewed studies reveal the result as the significant role of brain-based learning strategies in enhancement of the learning capabilities of the learners with learning disabilities. As brain-based instruction utilized the multisensory instructional techniques and constructivism teaching, which significantly improves the functions and habits of mind, it indicated children at risk with learning disabilities.

The brain-based strategies, like orchestrated immersion, relaxed alertness, and active processing, give the significant result of improved study habits and relieving test anxiety of students with learning disabilities. The brain-based learning approach incorporates interventions that utilize principles of BBL and BCL in the classroom, demonstrating that these strategies significantly improve the mathematical skills and scientific thinking of students with learning disabilities.

There is another study which utilizes the event-related brain potential correlates of event-based prospective memory in children with learning disabilities, where students with disabilities show poor performance compared to the non-disabled students.

Here it can be understood that brain-based learning can be applied in any form, like instruction programmes and theories, claiming the significance of improvement in the learners who are struggling with learning disabilities.

DISCUSSION

The formal learning helps in developing students' brains as it fosters the neural networks' integration.[19] This brain development can be hurdled by learning disabilities and disorders, as students struggle with disability, so the learning capabilities cannot be fully utilised.[20] As numerous findings suggest that learning disabilities cannot be cured, it can only be managed by the various interventions and enhancing the other learning capabilities, such as retention, academic achievement, and so on.[21] In the formal education system, teachers spend a significant amount of time with students, which can help them identify those who have learning disabilities through academic activities and behaviour.[22] A teacher is eligible to deal with the challenges that arise in helping learners with learning disabilities by utilizing various strategies, methods, and models that foster their learning capabilities.[23] As Hart says, teaching without knowing how the brain works is like making gloves without having awareness of how hands look.[24] So it becomes necessary to equip the teacher with neurological findings so the teacher can integrate neuroscience, which enhances the learning capabilities of learners with learning disabilities.[11] When teachers struggle to get expertise in aligning neuroscience with education, brain-based learning has the potential to provide the base for neurological evidence which can be aligned with the content and pedagogies.

This paper targets the studies that assess the effectiveness of brain-based learning or brain-focused teaching and learning of learning-disabled students. A study reveals that event-related brain potential shows the correlations, as with prospective memory in children with learning disabilities, which showed lower prospective memory as compared to non-disabled children.[15] Another study reflects that using the multisensory instructional techniques used as brain-based learning strategies to actively engage learners and allow them to construct their knowledge help in the enhancement of functions and habits of mind of learners with disabilities.[16] Multisensory engagement triggers the prefrontal cortex, superior colliculus (SC) and superior temporal sulcus (STS).[25] Multisensory simulations help learners with learning disabilities in increasing the cognitive function and memory-related capabilities by decreasing the neuropsychiatric symptoms.[26,27]

A study that three basic fundamentals of brain-based learning, namely 'orchestrated immersion', 'relaxed alertness', and 'active processing', help in improving the study habit and reducing the test anxiety in learners with learning disabilities.[17] Reducing anxiety helps the learner with a learning disability by improving learning and academic performance, positive changes in self-perception, and increased social skills that help in managing the learning disability.[28]

The left hemisphere of the brain deals with nonverbal learning disabilities, abstract and scientific thinking is triggered by this region.[9] A study reveals that the students with learning disabilities have lower mathematical skills as compared to children with no learning disabilities.[30] A study indicates scientific thinking and mathematical skills can be improved by implementing brain-based learning in the classroom by utilizing the principles of brain-based learning (BBL) and the principles of brain-compatible learning (BCL).[17]

For further studies it could be understood as that brain-based learning strategies are helpful in developing the

learning capabilities, like mathematical skill, scientific thinking, study habits, and habits of mind, in learners with learning disabilities. Numerous other studies reveal that brain-based learning strategies enhance the other learning capabilities, such as academic achievement, retention, self-efficacy, language-related skill, cognitive learning outcomes, and critical and creative thinking.[31-36] So these capabilities can be enhanced in the learners with learning disabilities, which helps in managing the hurdles caused by learning disabilities.

CONCLUSION

This paper reviews the studies related to brain-based learning and learning-disabled learners, which indicates that brain-based pedagogies help manage the learning disabilities by developing and enhancing the various learning capabilities that reduce the difficulties of learning-disabled learners. Brain-based learning helps in developing the various learning capabilities in learners who struggle with learning disabilities and learning capabilities, like mathematical skill, scientific thinking, study habits, and habits of mind. For further studies it could be suggested that brain-based learning has the potential to develop the various learning capabilities, so these capabilities should be inculcated in the learners struggling with learning disabilities. As this review paper reflects, very few studies have been done to assess the effect of brain-based learning on learning disabilities, so there should be more studies held to be targeting the learning disabilities by utilising brain-based learning in the general classroom.

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