20.0 Brain-Based Learning In Education: Principles, Strategies And Empirical Evidence

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Abstract

Brain-based learning (BBL) is an innovative approach grounded in the scientific understanding of how the brain learn. It aims to match teaching strategies to the way our brains naturally learn, process and store information. Based on the brain's natural learning process, this approach provides a scientific, learner-centric teaching and learning environment that enhances overall learning effectiveness. The present paper aims to examine the conceptual foundation, principles and key strategies of brain-based learning and to review empirical evidence regarding its effectiveness in improving students' outcomes. The study adopts a conceptual and narrative review approach based on an analysis of relevant literature from books, research articles, and scholarly publications in the fields of neuroscience and education.This article discusses the core ideas and twelve principles of brain-based learning, along with its instructional techniques. The paper also discusses various brain-based teaching strategies used to enhance classroom instruction. Additionally, the paper examined the benefits of brain-based learning, supported by empirical evidence, including improved academic achievement, enhanced memory and retention, development of higher-order thinking skills, enhanced engagement and motivation, reduced stress and anxiety and increased self-efficacy. The paper concludes the implications of the BBL strategy in the teaching-learning process for the holistic development of students.

Keywords: Brain-based learning (BBL), neuroscience, student-centric pedagogy

Introduction

Education is a dynamic discipline that continually evolves to meet the demands and challenges of students in a rapidly changing world. With the growing complexity of the contemporary world, conventional teaching approaches often fail to prepare students for real-world scenarios. As a result, continuous efforts are being made to improve teaching and learning methods. Teachers and researchers have been continuously exploring various teaching strategies to foster deeper learning, improve memory retention, enhance academic achievement and support students' holistic development. One of the ground-breaking ideas that has gained popularity in recent years is brain-based learning (BBL), an innovative teaching strategy that draws from neuroscience to optimise the learning process (Vipul& Narang, 2024).

From the ancient Gurukul system to today's constructivism, teaching methods and strategies have been greatly modified and restructured. However, very little attention has

been paid to the brain's function and its adaptability to new learning (Kunar & Mishra, 2019). However, discoveries in neuroscience have brought to light the complexity of the human brain and shown that learning is a multidimensional process influenced by the learner's physiological, psychological and cognitive states (Kumar, 2019). Brain-based learning considers this knowledge and applies neuroscience principles to create teaching strategies that mimic how the brain functions.

According to Varghesh and Pandya (2016), "Brain-based learning is learning in accordance with the way in which the brain naturally designs for learning". It combines the perspective from neuroscience and cognitive psychology to promote learning (Vipul & Narang, 2022; Varghesh & Pandya, 2016). One essential feature of BBL is to emphasise both cognitive and emotional aspects of learning. It also focuses on creating a learning environment where students are naturally motivated and engaged in the process of teaching-learning (Padhan & Yaduvanshi, 2025). Evidence shows that a positive emotional climate enhances memory and attention and cultivates overall happiness and well-being among students (Tyng et al., 2017; Alexander et al., 2021). Emotional and stress regulation is the main focus of brain-based learning. Research findings on BBL consistently show that it significantly improves conceptual understanding (Suarsana et al., 2018), knowledge retention (Uzezi & Jonah, 2017) and academic achievement among students (Kunar et al., 2019; Saleh & Subramaniam, 2019). This approach also reduces stress levels and enables better study habits among the students (Varghese & Pandya, 2016).

National Education Policy 2020 of India also prioritises learner-centred, flexi bleand holistic approaches to education to bring revolutionary change to India's educational system. The NEP 2020 promotes moving away from conventional, memory-based education and toward a more flexible, learner-centred approach that fosters creativity, inquiry and innovation. Brain-based learning supports these goals by creating dynamic, interactive, child-centred and brain-friendly learning environments that foster excellence and prepare students for the challenges of the 21st century.

Research Questions

The present paper seeks to address the following research questions-

1. What are the conceptual foundations of brain-based learning?
2. What empirical evidence supports the effectiveness of brain-based learning on students' outcomes?

Objectives of the study

1. To explain the core concept of brain-based learning.
2. To describe the major principles and instructional techniques of Brain Based learning.
3. To explain various brain-based teaching strategies used to enhance classroom learning.
4. To review empirical studies that highlight the effectiveness of Brain-based learning in improving students'outcomes.

Methodology

The present study adopts a conceptual and narrative review to examine the conceptual foundation, principles, instructional techniques, teaching strategy and empirical evidence related to Brain-based learning. The study draws on secondary data sources, which include books, peer-reviewed journal articles and other scholarly publications related to brain-based learning, educational neuroscience and cognitive psychology. The relevant literature was reviewed and analysed. Then, the collected information was thematically organised and synthesised under major sections such as Brain-based learning, twelve principles of brain-based learning, three instructional techniques of brain-based learning, brain-based teaching strategies and benefits of brain-based learning supported by empirical studies, discussed below-

BRAIN-BASED LEARNING

Brain-based learning refers to an innovative strategy that draws from contemporary scientific understanding of how the brain functions during learning. It takes insight from recent studies on the brain to develop a teaching strategy that aligns with the brain's natural learning process. It considers that learning is influenced by physical, emotional and environmental factors; therefore, it emphasises active participation, multisensory learning and an emotionally supportive learning environment to foster learning. According to Varghese and Pandya (2016), "Brain-based education is a neuro-cognitive approach to learning". It focuses on student learning and outcomes from a brain-based perspective. As per Caine and Caine (2006), "brain-based learning includes admitting the brain's rules for meaningful learning and adapting teaching with those rules in the Brain." This approach is grounded in twelve basic principles, which are derived from neuroscientific research on the brain.

Twelve principles of brain-based learning

The twelve principles of brain-based learning were developed by Geoffrey Caine and Renate Nummela Caine (Caine & Caine, 1991; 1994). It provides a theoretical foundation for brain-based learning and highlights how teachers adapt their teaching methods to the brain's natural learning process.

a. The brain processes information simultaneously

The human brain can perform several tasks or process different types of information, such as feelings, imagination, thoughts and behavioural patterns, simultaneously. By keeping the brain's parallel processing in mind, teachers can design lesson plans and incorporate activities that require students to think, feel positive and do simultaneously.

b. Learning involves the whole physiology of the human body

The process of learning is not only a mental activity, but it also involves the entire body. A person's physical health, e.g. physical development, nutrition, sufficient sleep, etc., significantly affects their ability to learn, understand and memorise information. For example, if a child does not sleep the previous night properly, then the next day, he/she will be unable to learn, process and memorise the information properly. Thus, the teachers can integrate various physical activities into their lessons, such as drama, role play, project work, etc., to

keep the students physically engaged. Teachers must prioritise students' physical well-being by promoting healthy nutrition and adequate sleep.

c. Meaning-seeking is a natural human tendency

Making sense of our experiences or seeking meaning are survival-oriented and fundamental aspects of the human brain (Masurkar, 2021). It is an innate ability of every individual to organise information and formulate questions about the concept, which makes them curious. To encourage students' intrinsic motivation, teachers can design curricula that are relevant to students'experiences and interests. Furthermore, teaching methods and teaching strategies used by teachers are based on considering individual differences as well as learners' real-life choices. It should include activities that satisfy the child's brain curiosity and promote exploration of new information.

d. Meaning is formed through pattern recognition

According to Restak (1996), "patterning refers to the organisation and categorisation of information". Our brain arranges all the information (both previously learned and newly acquired) into patterns. This process helps the brain understand and remember the concept more easily. Teachers should present content in a way that a student can identify patterns and correlate with previous knowledge.

e. Emotion strongly influences the pattern formation

Emotion and cognition cannot be separated. Studies on the brain have revealed that our feelings and emotions greatly impact the formation and maintenance of patterns in the brain. Emotions are crucial for memory formation and the retrieval of information. Creating a positive emotional environment in the classroom is very much necessary. Activities that are meaningful, interactive and related to the students' interests can create positive emotions among students and help to create strong memory patterns.

f. The brain processes parts and wholes at the same time

The human brain is divided into two hemispheres. The first is the left hemisphere, and the second is the right hemisphere. Both hemispheres process and organise information simultaneously. One breaks down information into smaller pieces, and the second processes information in a more holistic way (Caine & Caine, 2003). This means that our brain can handle both the details (parts) and the overall picture (whole) at the same time. Therefore, at the time of teaching, there is a need to include both small details and overall pictures to gain a deeper understanding of the subjects.

g. Learning occurs through both focused attention and surrounding perceptions

This principle of brain-based learning states that learning requires paying close attention to specific details (focused attention) and being aware of the surrounding environments and context (peripheral perception). Teachers can capture students' attention by using engaging activities, presenting relevant real-world examples and other various strategies. and support peripheral learning by creating a stimulating, learner-friendly environment. Teachers can use various visual aids, background music, posters and charts to capture students' peripheral perceptions.

h. Learning engages conscious and unconscious processing

We learn through both conscious (deliberate) and unconscious (automatic) processes. Conscious learning happens when we focus and are aware of what we are doing, for example, paying attention in class. But our brain also constantly picks up information from the environment when we are not paying full attention. We learn more effectively and efficiently due to this dual approach of working together.

i. Humans have two main types of memory: spatial and rote memory

The brain relies on both spatial and memorisation-based memory. Rote memory involves memorisation of facts or information through repetition and practice, and spatial memory is associated with context and experience. Both types of memory are significant for learning. Teachers should be provided with both spatial learning circumstances and theoretical information. Also, teachers need to avoid too much emphasis on memorisation, as this obstructs the future growth of Knowledge (Vipul & Narang, 2024).

j. Learning is most effective when facts and skills are encoded through spatial memory

We remember the information more effectively when it is connected with our real-life experience. Spatial memory is stimulated through experiential learning. For example, if we learn and remember a recipe better while we cook in the kitchen. We remember a concept more easily when we learn in a familiar environment or when we connect the new information with what we already know. Teachers can incorporate various real-world activities into their lessons, for example, projects, field-trips and storytelling, to connect with the students' spatial memory.

k. Appropriate challenge supports learning, whereas threat reduces it

The human brain learns best when things are a little challenging but not too hard. Research on the brain has revealed that stressful and threatening environments can negatively impact the learning process (Kumar, 2019). Therefore, it is important for educators to create a learning place where learners feel safe and supported. In this way, students can learn and grow without any pressure.

l. Each brain is unique-

Every individual follows a similar pattern for growth and development; however, individual differences occur. We all experience the same fundamental feelings, thoughts and emotions, but our brains process them differently. Every individual has their own unique way of patterning or learning. So, educators should modify their teaching strategy to each student's unique learning preferences. He or she can employ a variety of exercises and provide clarification in different ways.

Instructional techniques of brain-based learning

Three interactive teaching strategies emerge from the twelve principles of BBL proposed by Caine and Caine in 1999. These are as follows-

a. Orchestrated immersion-

This is the process of establishing a classroom setting in which pupils are totally absorbed in the lessons being taught, and it must be surrounded by teaching and learning materials. These

environments help the students to remember the concept better than just listening to a lecture or reading a book (Ramakrishnan &Annakodi, 2013; Varghese & Pandya, 2016). One example of Orchestrated immersion is engaging students in a foreign culture to teach them about a foreign culture.

b. Relaxed alertness-

This refers to creating a classroom where all students feel safe, confident and free to make mistakes. This encourages students to share their thoughts and ideas without fear of judgment. Furthermore, active participation and discussions are promoted. This stimulating learning environment helps learners perform at their best without feeling stress and anxiety. It promotes the emotional well-being of students.

c. Active processing-

Active processing is the process of enabling a learner to actively and completely interact with the material in order to assimilate, internalise and relate it. Active processing allows the students to maximise the use of their senses actively and connect new knowledge with their past experiences (Vipul& Narang, 2024).

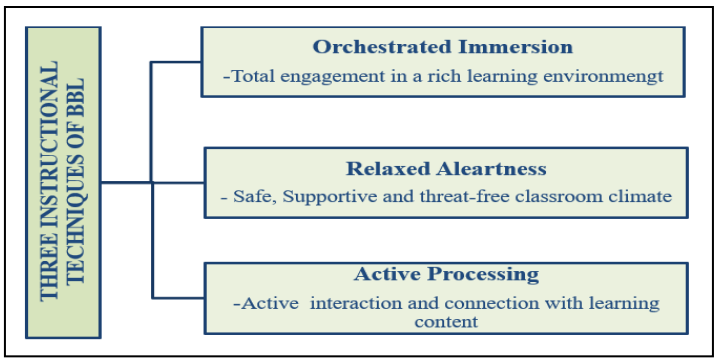

Figure 1: Three Instructional Techniques of Brain-Based Learning

Brain-based teaching strategies

If the teacher knows how the human brain works best, then he or she could create an atmosphere that enhances learning. BBL strategies help the teacher create a brain-friendly learning environment where students learn best.

In a brain-compatible classroom, teachers use various strategies to optimise students' learning outcomes. The following are some common Brain-based teaching strategies –

a. Chunking information

Information is learned more easily when it is presented in small parts or chunks. Chunking is the most effective strategy that supports the brain's natural ability to organise and retain information in a meaningful pattern (Chekaf et al., 2016; Suppawittaya &Yasri, 2021).

b. Multisensory learning

Multisensory learning involves using various visual, auditory and kinaesthetic elements in lessons to engage multiple senses simultaneously. Research has shown that incorporating multiple senses activates various neural pathways, which enhances cognitive performance (Paraskevopoulos et al., 2024).

c. Emotionally safe learning environment

Emotions and cognition cannot be separated. They are interconnected, and they work together (Levine, 2022).**"**According to Tyng et al. (2017), emotions have a major impact on cognitive functions such as perception, attention, learning and information storage and retrieval". Therefore, an emotionally safe learning environment is critical to brain-based learning.

d. Building on Prior Knowledge

Building on prior knowledge is a key strategy of BBL. Memory function and retrieval of information rely on the ventromedial prefrontal cortex and the hippocampus of the brain, and our previous knowledge influences it (Guo et al., 2023). The brain activates existing neural networks when students relate new information to previous knowledge, and when these connections are used more, the connections become stronger, which leads to long-term memory retention.

e. Incorporate movements

Movement stimulates various areas of the brain. It improves the blood flow and oxygen supply to the body. Research has proven that Physical exercise enhances cognitive functions like focus, memoryand thinking skills (Festa et al., 2023). Activities like standing, participating in indoor games, etc., are very practical for effective learning.

f. Brain breaks

The brain cannot take too much information at a time. When learners engage in learning for a long time, their ability to process and retain information gradually decreases due to mental fatigue. Teachers may give students a short break during the learning time. Teachers can also use various brain break strategies like physical movements, mindfulness exercisesand simple, fun activities to refresh the mind.

g. Frequent feedback

Practice doesn't make anything better unless the practice is accurate (Ramakrishnan & Annakodi, 2013). Students need to understand whether they are on the right track or not. Positive Feedback activates the brain's reward system and motivates students to become more aware of their learning processes. It boosts memory more than just re-reading (Wiklund-Hörnqvist et al., 2017).

h. Music and art

Incorporating art and music is a key strategy of brain-based learning reinforces multisensory engagements. Art and music stimulate multiple areas of the brain, help to regulate emotion and enhance cognitive function (Särkämö et al., 2013). Research has also proven that music not only improves cognitive function but also helps to reduce depression, anxiety and stroke rehabilitation (Toader et al., 2023).

Benefits of brain-based learning

Research has shown that BBL has a broad range of benefits. The following are some of the important benefits of BBL, which have been proven through various studies.

a. Improving academic performance

One of the primary benefits of the BBL strategy is that it improves students' academic achievements. Empirical studies confirm that students who are exposed to BBL strategies such as active engagement and multisensory learning, emotional engagement, etc., demonstrate significantly higher academic achievements. In their study, Kuna & Mishra (2019) found that BBL strategies significantly improve academic achievement in science among students. Research studies by Alanazi (2020), Erol & Karaduman (2018), Orengwu et al. (2020), and Varghese & Pandya (2016) have also proven that this sterategy significantly improves the achievement of students.Amjad et al. (2022); Shabatat & AL-tarawneh (2016); Saleh & Subramaniam (2019); and Olaoluwa & Ayantoye (2016) also found that students who use BBL perform significantly better than those using the traditional teaching method. All these studies highlight the effect of the BBL strategy in improving academic achievement across various subjects and student populations.

b. Enhance memory and retention

Memory plays an essential role in learning. It enables people to retain and retrieve information for a long time. Studies confirm that brain-based learning strategies significantly improve memory retention among students (Tufekci&Demirel, 2009). The brain encodes information better when it is present in a meaningful way and an emotionally engaging context. Various brain-based techniques like chunking information, repetition and storytelling not only improve knowledge comprehension but also promote long-term memory retention. Uzezi& Jonah (2017) in their studies found that the BBL strategy has a positive impact on students' knowledge retention. Studies by Koşar& Bedir (2018), Haghighi (2013)and Handayani& Purwati (2022) also revealed that brain-based learning significantly improves retention of concepts among students. Sani et al. (2023) and Eladl and Saad (2019)found that BBL methods enhance the working memory of students, which supports more effective information processing and long-term retention.

c. Develop higher order thinking skills

BBL not only improves students' achievement but also develops higher-order thinking skills such as critical and creative thinking. Our traditional teaching methods mainly promote rote memorisation, which is not suitable for promoting deeper thinking. Brain-based learning encourages learners to actively involve, think critically and understand the concept deeply by connecting the concept with real-life scenarios that promote higher-order thinking skills. Several studies support this view. Studies by Ramakrishnan &Annakodi (2015); Maryati et al. (2020); Saeed & Kayani (2025), and Zakaria & Purwoko (2020) show that the BBL method is more successful than the conventional method to enhance student creativity and critical thinking. Akcay et al. (2023) found that brain-based learning significantly enhances metacognitive awareness of students. All these findings prove that BBL significantly boosts higher-order thinking skills among students, which are essential to achieve success in today's world.

d. Increase students' engagement and motivation

Brain-based learning focuses on creating an interactive, emotionally supportive and friendly learning environment that improves engagement and motivation of students in the classroom. Akyurek and Afacan (2013) found that instruction based on brain-based strategy increased students' enthusiasm and motivation in Science and Technology. Similarly, the results of Uzezi and Jonah (2017) showed that BBL strategies had a positive impact on students' attitudes and motivation. Salem (2017) also found that these methods significantly increased listening skills and motivation among students. All these studies clearly show that brain-based learning creates an attractive and motivating learning environment.

e. Reduce stress and anxiety and improve students' self-efficacy

As per studies, stress and anxiety negatively affect students' concentration and motivation, which negatively impact student learning, memory and cognitive function (Rowe & Fitness, 2018; Amran et al., 2019). Brain-based learning focuses on creating an emotionally supportive and safe learning environment that reduces stress and anxiety among students. Varghese & Pandya (2016) from their study found that BBL not only improve the academic performance of students but also lowers their stress levels. It also decreases student anxiety and improves study habits among them (Nassar, 2019; Vipul & Narang, 2019). Additionally, it not only decreases stress and anxiety among students but also improves self-efficacy among students, which is essential for effective learning and academic success (Oghyanous, 2017; Riskiningtyas &Wangid, 2019).

Conclusion

Brain-based learning offers a scientific, learner-centred, well-researched and innovative approach to education by aligning the teaching strategy with the brain's natural learning processes. This approach aims to create an effective, engaging and joyful learning environment by taking insight from neuroscience in classroom practice. Empirical evidence shows that brain-based learning strategies develop high-order thinking skills, increase motivation, reduce stress and anxiety and promote self-efficacy among learners. Integrating BBL strategies such as active learning, emotional engagementand brain breaks helps students learn and retain information better and promotes a deeper understanding of the concept. Therefore, the adoption of BBL in classroom practice holds significant potential to enhance learning effectiveness and foster the overall development of learners.

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