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Research Article

The Effect of Brain-Based Learning Strategy on the Development of Academic Achievement Levels in Biology Course amongst Tenth Grade Students

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ARTICLE INFO	ABSTRACT

The purpose of this study was to demonstrate the impact of brain-based learning strategy as an instructional strategy on the academic achievement level among tenth grade students in the field of life sciences. The researchers adopted a quasi-experimental approach. Four-eighty male and female students are participants of this study. The school was chosen randomly from the Latin Patriarchate Mixed Schools in Jordan because the school administration agreed to collaborate with the researcher. The sample was divided into two groups: Group A, the experimental group taught the brain-based learning strategy, and Group B, the control group taught the conventional strategy. To achieve the objectives of the research, the researcher prepared the teacher's guide and the suitable activities for the new strategy. After the preparation, the researchers used pre-test and post-test for measuring the academic achievement level of the students. The data was analyzed using descriptive statistics, one-way and two-way analysis of variance. The results show that there is a relationship between overall and detailed level academic achievement students' outcomes and the groups. The results also indicate no significant difference between genders in the study due to interaction with the strategy in teaching life sciences and the overall and detailed level as domains of analysis. The researcher formulated some recommendations, by the study's results, that the brain-based learning strategy helps the academic achievement levels in the teaching of life sciences.

Keywords: Brain-based learning strategy, academic achievement, life sciences, tenth grade.

Introduction

As humans develop, ways of thinking develop, and the cognitive capabilities of the human brain follow modern learning and education strategies. The human brain learns something new with the development of modern technologies that allow for a greater ability to absorb and process information. To study the emerging learning mechanisms of the human brain, we need to understand the nature of the human brain, including its structure and function. This requires a modern approach in medical research to understand its complex nature and develop new strategies for communicating with the human brain in its natural conditions. Nowadays, in this century, the number of modern diagnostic methods and techniques used by obstetricians to detect the fetus in utero is increasing, and there is great interest in the stages of child development in order to track the changes occurring in this phase. All this has led to a new, qualitative method of scientific research, the aim of which is to activate brain research for the educational process. Scientific research, in light of ongoing efforts to understand the mysteries of the brain, has also begun to explore ways to use this knowledge in the service of education. Therefore, the world must remain intellectually connected to the latest developments in this field of science to improve educational outcomes and achieve natural learning that is consistent with the reality of the brain and human nature (Deeb, 2005).

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It has been found that keeping up with the abundance of brain research conducted over the past two decades is challenging. Applying these theories and research to the educational process can have a significant impact on success. The result is an innovative learning method that is consistent with the brain's natural learning processes, based on research in neuroscience, diagnostic radiology, behavioral neuroscience, cognitive psychology, and biochemistry. This is how the term “brain-based learning” or “brain-aligned learning” emerged and has had a profound impact on teachers and students around the world. Understanding the relationship between learning and the brain now includes the role of emotions, patterns, meaning, environment, body rhythms, orientation, stress, nervous shocks experienced by individuals, judgment processes, music, movement, gender, and enrichment of learning (Jensen, 2007).

The concept of learning is closely related to the processes of acquiring behaviors and experiences and the changes that occur in them. The results of the learning process are manifested in various aspects of human activity, including intellectual, physical, social, emotional, and linguistic dimensions. Human experiences and knowledge accumulate and are transmitted from generation to generation through socialization processes and interaction with the material world (Al-Zughoul, 2003).

Scientists argue that outdated teaching methods should be replaced, which do not contribute to the understanding of complex scientific mechanisms and hinder self-education. Such methods may not lead students to the full reality of science, and modern approaches emphasizing three-dimensional perspectives and experimentation are seen as essential. Learning, especially biology and molecular biology, benefits from a basic understanding of information and clarity of purpose before experimenting. Recent scientific developments, discussed by Brothers (1989), emphasize that brain-based sciences provide an understanding of how students think, enabling educational advancements to consider individual differences and create a unified mental fabric adapted to diverse cognitive profiles.

Molecular biology focuses on the three-dimensional structures and configurations of biological molecules and studies form and function. To raise students' academic level and solve current problems, modern approaches and new tools are necessary (Jensen, 2007).

Academic achievement refers to measurable outcomes that indicate the level to which an individual has achieved specific goals that have been the focal point of activities in educational settings, particularly schools, colleges and universities. School systems most often define cognitive goals that either apply to multiple subject areas (e.g., critical thinking) or involve the acquisition of knowledge and understanding in a specific intellectual domain (e.g., science). Therefore, academic achievement should be considered a multifaceted construct that encompasses various domains of learning. Because the field of academic achievement is very broad and encompasses a wide range of educational outcomes, the definition of academic achievement depends on the indicators used to measure it (Steinmayr, Meißner, Weidinger, & Wirthwein, 2014).

Scientists argue that academic achievement refers to progress and achievement in acquiring educational skills, materials, and knowledge in various disciplines. Specifically, it denotes achievement in academic settings, distinguishing it from the acquisition of general knowledge outside academic contexts. Access to scientific thinking and the use of scientific skills fully support levels of academic achievement, which helps organize learning goals. When science skills are integrated, students achieve the cognitive levels listed in Bloom's Taxonomy. It is well known that academic achievement has a significant psychological impact because it is a principal factor in increasing students' self-confidence. It supports the individual not only on a personal level but also in various other aspects of life. Academic achievement is the real gateway to success, even in terms of specialization or employment, because it increases students' options and gives them freedom of choice. Additionally, for students with low academic achievement, it can alleviate the constraints they face in a competitive job market often filled with limited opportunities.

Science continues to hold a dominant position that has a significant impact on students' lives. Many studies have shown that student achievement in science in Jordan is poor. For example, Ba'ara in his study (2002) sought to identify barriers to science education that may have impacted student achievement in Jordan. Bani Khalaf (2011) also found deficiencies in science learning among students tenth graders. Moreover, a report by the National Center for Human Resources Development (2019) revealed that the daily assessment conducted by the Trends in International Mathematics and Science Study (TIMSS), along with many of its indicators, indicate a decline in the achievement of Jordanian students, both at the eighth-grade level and across trial in skills such as classification and analysis. Jordanian averages were also lower than international averages in skills such as reasoning and problem solving.

All these critical factors that hinder students' learning and overcome weaknesses led researchers to develop a brain-based learning-dependent educational program and then measure its impact on the academic achievement of tenth-grade students.

The problem of the study and its questions

Jordanian students' scores on the Program for International Student Assessment (PISA) have fluctuated, with scores considered good in the Arab context but modest globally. In the PISA exam, Jordanian students score an average of 429 points compared to the OECD average of 489 points. Women outperform economics by 29 points, consistent with the OECD gender trend. In the 2018 international science rankings, Jordan was ranked 51st out of 78, an improvement of 18 places. However, the Jordanian Ministry of Education's Strategic

Plan (2018-2022) notes weaknesses in academic achievement, low success rates at secondary school level, and insufficient skills in scientific processes. Baara (2002), Bani Khalaf (2011) and Ministry of Education (2019) confirm these findings.
Based on the above, this study was conducted as an attempt to investigate the impact of a brain-based learning teaching strategy on promoting academic achievement levels in life sciences among tenth-grade students in Jordan. Considering this, the study sought to address the following two questions:

- Are there statistically significant differences at the level of significance (α = 0.05) between the mean scores of the two study groups on the comprehensive and detailed academic achievement test assigned to the teaching strategy (brain-based teaching strategy and conventional strategy)?
- Are there statistically significant differences at the level of significance (α = 0.05) between the mean scores of the two study groups on the Comprehensive and Specific Academic Achievement Tests, attributable to the interaction of gender and teaching strategy (brain-based teaching strategy vs. conventional strategy)?

Study objectives

By asking the first question, the study also aimed to demonstrate the effectiveness of a brain-based learning strategy in science education and to examine its impact on improving the academic achievement of tenth-grade students in Jordan compared to a conventional strategy. In addition, the second question aimed to examine the interaction effects of gender and teaching strategies compared to conventional strategies in the field of academic achievement testing.

The importance of the study

The significance of the study is the development of a contemporary strategy rooted in brain science to improve teaching methods, adapting to global scientific progress. It contributes to the Arabic research library by offering valuable insights to researchers and educators. In practice, it provides educators, biology educators and caregivers with insight into the impact of brain-based learning in science education, motivating students to improve skills and improve academic performance. The school's role includes developing science skills, motivating high-achieving students and encouraging students who are less interested in science. Curriculum planners, science educators, and training programs can benefit from reorganizing curricula to prioritize science literacy. Additionally, it provides an applied model for brain-based learning, laying the foundation for future research in a similar topic area.

Study Terminology and Procedural Definitions

This study includes the following procedural definitions:
Brain-Based Learning Strategy: It is a comprehensive approach to education and learning, based on the principles of modern neuroscience that explain the natural functioning of the brain. It is based on current knowledge about the anatomical structure of the human brain and its functional functioning at various stages of development (Al-Salti, 2009).
Operationally, it is defined as a procedural plan and activities designed by researchers using a comprehensive approach to education and learning based on the assumptions of modern neuroscience. These activities are consistent with the natural learning processes of the brain, drawing on the anatomical structure and functionality of the human brain. The teacher implements these activities in an organized manner according to the desired scientific approach to achieve educational goals with tenth grade students.
Academic achievement: As defined by Lynn and Kelly (2001), it refers to the academic effort made by a student in educational situations, the purpose of which is to increase the level of acquisition of information and knowledge within a specific educational domain.
Researchers, however, define it procedurally as the scientific effort that tenth-grade students undertake in educational situations and during their involvement in the school environment, aimed at increasing the level of acquisition of knowledge and understanding and achieving cognitive levels (recall, understanding, application, analysis) within teaching strategy based on brain-based learning. They also pass an academic achievement test prepared by researchers.

The study's scope and limitations

The study examines the impact of an educational strategy based on brain-based learning on academic achievement levels in life sciences among tenth-grade students. Therefore, its scope is defined as follows:

- **Geographical boundaries:** The study was conducted at the Latin Patriarchate School in Al-Fuheis, under the authority of the Ministry of Education.
- **Human boundaries:** The implementation of this study was limited to tenth-grade students.
- **Temporal boundaries: This study was conducted from October 2, 2021, to November 15, 2021, in the first semester of the academic year 2020/2022.**

- **Subject boundaries:**
  - The study was limited to a specific unit of the biology subject curriculum, the activity book, and the scientific experiments for the tenth grade. This unit focused on the classification of living organisms and was divided into three main sub-parts: bacteria and archaea, protists, and fungi.
  - The tool used in the study, which is the academic achievement test, was developed by the researchers. The accuracy of the study results and their generalizability depend on the validity and reliability of this tool.
  - The study was limited to four levels of academic achievement: remembering, understanding, applying, and analyzing.
- The generalizability of the results of this study depends on the appropriateness, validity, and reliability of the tool used.

Theoretical Framework and Previous Studies

The first framework is the theoretical framework, which is divided into two main axes:
- Academic achievement: Measurement of academic achievement, factors influencing academic achievement.
- Brain-based learning theory: Discussion of the brain with its two hemispheres, the concept of brain-based learning, principles of brain-based learning, and factors influencing brain-based learning.

Academic achievement

Academic achievement is considered one of the most important educational outcomes and is of significant importance to individuals and their families. In addition to successfully completing educational milestones and obtaining grades to qualify for further study, academic achievements have important implications in life, such as the choice of education and career. It also affects their self-perception, sense of success and level of ambition. Educational institutions typically measure students' academic achievement to provide feedback on their mastery of learning skills, evaluate teachers' efforts, and assess the effectiveness of the curriculum in achieving educational goals. Therefore, it is important to choose teaching methods, strategies and models to improve students' academic achievements (Al-Qarra'a, 2018).
Al-Sha'ili and Al-Balushi (2006: 45) define it as "what a student acquires in terms of knowledge, skills and values after going through subject-specific learning experiences and situations."
Taha (2003: 183) defines it as "used to refer to the ability to meet the requirements for academic success, either in terms of overall or qualitative achievement during a specific period of study."
The following is a definition of academic achievement levels as defined by Anderson and Krathwohl (2001):
Recall (knowledge): It means the learner's ability to search for specific facts and information, representing the lowest results in the cognitive domain. It involves recalling mathematical knowledge from memory without implying understanding or interpretive ability.
Comprehension: It involves capturing the meaning of learning content, enabling students to interpret and explain concepts, scientific principles and phenomena. This level goes beyond mere recall, indicating a higher understanding.
Application: It reflects a student's ability to apply learned concepts, facts, and principles to new situations, demonstrating a more advanced level of thinking than recall and understanding.
Analysis: This entails breaking down learning material into components, identifying relationships, and understanding organizational structures. Analysis, as a complex cognitive process, requires thinking at a higher level than recall, understanding and application.

Factors influencing academic achievement

The rapid increase in the number of people enrolling in higher education has increased the importance of academic achievement (Ballafkih and Middelkoop, 2019). Nevertheless, approximately 30% of students leave college without obtaining a degree, which is a challenge (Altbach, Reisberg, & Rumbley, 2009; Yorke & Longden, 2007).
Educational psychologists study personal characteristics, cognitive factors, and environmental influences. Shortcomings in the curriculum and environmental factors, including overcrowded classrooms, affect academic performance (Al-Astal, 2010; Al-Halibi and Al-Rayashi, 2000).
Classroom design is critical, and scientifically proven models demonstrate the potential to improve concentration and positively impact achievement (Zengin, 2017). Considering these factors is essential to promoting academic success.

Factors influencing academic achievement can be categorized into various aspects

Personal factors: Individual characteristics such as intelligence, motivation and learning style influence academic performance.

Cognitive Factors: Memory, critical thinking, and information processing skills are crucial to retaining knowledge.
Environmental Factors: Both school and out-of-school environments, including the quality of teaching and family support, contribute to academic success.
Socioeconomic factors: Income, parental education, and occupation can influence educational opportunities and achievement.
Peer Influence: Positive peer relationships support academic success, while negative influences can hinder achievement.
Parental Involvement: This may include Parental encouragement, support, and involvement positively to impact student's motivation and success.
Cultural and ethnic factors: These include differing cultural beliefs and educational expectations influence attitudes, goals, and learning styles.
Each of these factors contribute to, and reinforce, one another; they work in a dense network of probabilities to influence educational success. When restricted, they limit the extent to which certain configurations of said factors can emerge, benefiting the production of educational contexts for successful students.

The Interconnected Relationship between Academic Achievement and Scientific Skills

The relationship between learning processes and academic achievement is complex and mutually influencing. Learning processes are based on cognitive operations such as thinking, analyzing, and synthesizing, therefore students who are good at such processes will achieve good academic results. In turn, good academic performance can improve their self-confidence, critical thinking, and problem-solving abilities, which in turn positively affect learning processes.
Al-Wahar, Al-Hamouri, and Abdulmajeed (2008) pointed out that conditions and factors can have a massive impact on good academic performance and shortcomings of educational programs. Mustafa (2001) links academic delays to mismatches in program implementation. Recent research has shown a positive correlation between learning styles and academic achievement.
Mastering scientific processes, including observation and reasoning, significantly affects academic achievement. Proficiency in these skills enhances integrated skills such as interpreting data and formulating hypotheses. Al-Baali (2012) confirms the close relationship between scientific processes and the growth of academic achievements, emphasizing their strong correlation.
Teaching critical thinking is crucial to academic development. Equipping students with scientific process skills promotes inquiry-based learning, scientific discovery, and problem solving in academic and real-world scenarios (Myers & Dyer, 2006).

Brain-Based Learning

The characterization of brain-based learning theory emphasizes that it is "an integrated system in itself, rather than a pre-designed structure. It is a multidisciplinary approach drawn from various fields such as chemistry, neuroscience, psychology, genetics, biology, and computer science (Jensen, 2000: 107). This theory has led to the emergence of two contradictory types: the first is learning that relies on and is harmonious with the brain, while the second is the opposite, working against the brain's pull signals, causing them to not learn properly (Al-Salti, 2004). Because this theory is based on the functioning of the brain and its unique structure, and the brain is not prevented from carrying out its natural processes, the learning process occurs naturally. Brain stimulation (in brain-based learning theory) generates enormous energy of readiness to accept learning that is not present in the usual way, which sometimes fails in the learning process due to lack of encouragement and brain stimulation. This may hinder the learning process because it lacks the natural processes that occur in the brain (Bruer, 1999).
Brain-based learning, as an instructional strategy, is a natural approach that does not involve many of the educational complexities that other strategies do. It is based on the brain in its natural state, specifically integrated brain functions. Scientists have been trying to understand the content and basic functions of the brain for centuries. They used various methods to discover neural connections, the representation of glucose, study its parts, and track neuronal development. However, due to the complexity of the human brain, scientists have failed to fully understand its nature. As medical technology advances, particularly in brain imaging using positron emission tomography (PET), scientists have made progress in deciphering the mechanisms of the human brain (Jensen, 2007).
After dominating the field for several centuries, especially since the early 1950s, behaviorist theory, founded by American psychologist John Watson, emphasized the importance of the environment in shaping individual behavior. Behaviorists focused their research on the relationship between observable behavior and environmental stimuli. Notable figures associated with this theory include Watson, Pavlov, Thorndike, Skinner, and Bandura.
An important feature of this theory is the principle of reinforcement and punishment. Psychologist Skinner (Skinner, 1953) emphasized that the most effective way to teach individuals is to adjust their minds through rewards and punishments. This theory continues to influence educational settings and continues to have

supporters and advocates, even half a century after its inception. This happens because old ideas find a comfortable home in the minds of administrators and teachers who fear the unknown. They believe that sticking to proven methods gives a sense of confidence and security.

Due to the cumulative nature of science, which is based on the accumulation of human knowledge from different fields, different theories and strategies may have similarities in some areas but differ in approach and reasons. Brain-based learning theory may also share similarities with other theories and strategies, although it intersects in specific areas and differs in ideas and causes. Because brain-based learning theory is an extension of discoveries in educational science and a natural progression of other learning theories, it incorporates previous theories to improve the educational process and pedagogical methods (Abuhatb and Sadik, 1992).

This theory is like Skinner's behaviorist theory, which views learning as a close relationship between neural connections in the nervous system that develop under the influence of stimuli as components of the nervous system. The prominent principles of this theory are as follows:

- Learning is a result of the learner's experience, experiments, and the influence on their responses.
- Learning is associated with procedural behavior that is intended to be developed.
- Learning is built through reinforcing performance that is close to the typical behavior.
- Learning associated with punishment is considered negative learning.

Although there are some conceptual similarities between Skinner's theory of behaviorism and the new brain-based learning theory, there are also some significant differences. The theoretical framework and associated neural mechanisms are not the same. According to Skinner, learning is related to neural connections in the nervous system and stimuli from the environment, and behavior is reinforced or inhibited by punishment or reward. In the new brain-based learning theory, attention is focused on the brain's functions and related neural systems that appear related to learning. Learning is characterized by being derived from complex neural interactions in the brain, involving systems based on chemistry, neuron firing, psychology, genetics, biology, and even computation.

Unlike behaviorist theory, which relies solely on observable behavior and external stimuli, brain-based learning theory focuses on internal brain processes and their impact on learning and academic performance. Brain-based learning theory can be viewed as an evolution of previous educational theories, using knowledge from neuroscience and other scientific disciplines to formulate learning and enhance educational methods.

Overall, although there are some similarities and similarities between the behaviorist learning theory associated with Skinner and the brain-based learning theory, they are distinct theories that independently focus on different mechanisms or components of the learning process. Each learning theory provides a lens through which learning can be viewed - one theory emphasizes external behavior and its associated stimuli (as was the case with behaviorist theory), while the other theory focuses on internal neural and cognitive processes taking place within the brain and which form the basis of learning.

As a result of extensive educational research, new theories have emerged advocating the need to focus on the student, rather than the teacher, as the central element of the educational process. This led to the development of cognitive theory, pioneered by the psychologist Bruner, who contributed to the development of cognitive psychology and cognitive learning theories in the areas of educational psychology and educational philosophy. Bruner's principles are based on classification theory, which states that "perceiving is categorizing, imagining is categorizing, learning is constructing categories, and deciding is categorizing." It was from Bruner's classification theory that the idea of relying on the mind (the human brain), brain processes and neuroscience to understand its mechanisms and vital functions arose, leading to the application of this knowledge to a new brain-based strategy. This strategy is called brain-based strategy or brain-informed strategy (Jensen, 2007).

The concept of brain-based learning only emerged in the 1980s due to advances in neuroscience and cognitive neuroscience (Jensen, 2008). Hart (1983) was one of the first researchers to establish the relationship between brain functions and conventional educational practices in his book Human Brain and Human Learning. He also explained that traditional classroom practices prevalent in most schools significantly impede students' cognitive processes (Degen, 2011). Baqsmawi (2006) claims that if we allow the brain to perform its natural functions without hindrance, learning will definitely occur. He emphasizes that every human can learn because humans are born with a powerful processing brain. However, traditional schools often hinder the natural learning process through fear, ignorance, and rigidity. He sees this theory as an integration of various fields of science, such as physiological and biochemical neuroscience, medicine, computer science, and educational science.

Researchers continued to explore the concepts introduced by Hart (1983) and expanded their understanding of brain function in the context of learning. For example, Gardner (1983) established a link between brain functions, new thinking models, and learning in his book Frames of the Mind: The Theory of Multiple Intelligences. Additionally, Caine and Caine (1990) linked brain functions to classroom teaching principles in their book Making Connections: Teaching and the Human Brain. These researchers contributed to the study of the relationship between brain functions and various aspects of education.

Educational researchers such as David Sousa, Suzan Kovalik, and others, as mentioned by Awwad (2016), have shown interest in the theory of brain-based learning in an educational context that aligns with how the brain functions to achieve optimal learning. They aim to activate specific activities that are consistent with nature's brain functioning. Education involves individuals' perceptions and specific interests that accompany them in the early days of their lives, and these perceptions and interests are nurtured and developed over time through experience. Moreover, this experience leads to physiological changes in their bodies, primarily in the brain, which in turn affects their thinking processes (Thompson, 2014).

Some researchers, including Jensen (2008), Caine and Caine (1990), and Hart (1983), have focused on using neuroscience research to develop brain-based learning strategies. Their goal is to improve learning in accordance with natural brain processes (Degen, 2011).

Brain-based learning theory is based on an integrated system in which cognitive and perceptual aspects are linked to the physiological (functional) aspect of the brain. Every human brain can learn, regardless of age, gender or cultural background. It is equipped with a set of skills that allow it to explore various patterns, engage in self-correction, learn and gain experience through information analysis, self-reflection and, consequently, creativity and innovation (Al-Sulti, 2004).

Brain-based learning theory, which emerged from brain research, emphasizes learning through mental engagement, activity, and effectiveness (Learning with the Brain in Mind). This requires stimulating the brain, providing the desired motivation and motivation to accept learning. In addition, it is necessary to give meaning and relevance to what students learn, promote enjoyment in the learning process, eliminate hazards, and incorporate multiple sensory stimuli into the educational process, and other features that contribute to the effectiveness of brain-based learning (Jensen, 2000).

The concept of brain-based learning

The concept of brain-based learning is defined as "learning that aligns with the natural way" (Jensen, 2007: 12). Al-Salti (2004: 108) defines it as a "comprehensive approach or method of teaching and learning based on the assumptions of modern neuroscience that explain how the brain naturally functions and is based on what is currently known about the anatomical structure of the human brain or its functional performance in different developmental stages".

Kempermann and Wiskott (2004) define it as the integration of strategies based on the interaction of the body and mind, relying on brain research.

Erickson (2007: 5) defines it as "learning that involves designing and orchestrating a vibrant learning environment, rich with experiences relevant to learners, ensuring that learners process their experiences in a way that helps them derive meaning from these experiences".

Studies such as Caine and Caine (2014), Ibrahim (2011), Jensen (2010), Al-Abassi (2010), Afana and Al-Jaish (2009), and Obaidat (2003) **have confirmed that brain-based learning is based on a set of principles summarized as follows:**

1- **Learning engages physiology**: the brain and body function as a single unit whose stimuli stimulate mental functions. Motivation, physical interaction, and the use of the senses enrich the learning process.

2- **The brain/mind is social**: Social experiences shape the brain from early sensory input, contributing to the development of students' scientific skills.

3- **Innate search for meaning**: Signals are analyzed by the brain and our brain starts looking for meaning from the very first signals, the moment they are received and interpreted.

4- **Meaning through patterning**: The brain organizes meaning through mental models, patterns that combine new and old information into a model.

5- **Learning requires attention and perception**: Central attention and peripheral perception help the brain focus on central stimuli while maintaining awareness of signals from the surrounding environment.

6- **Emotions are central to patterning**: learning involves emotionally important hormones such as serotonin, oxytocin, and dopamine.

7- **Simultaneous processing of parts and wholes**: The two hemispheres of the brain are connected so that analysis and synthesis can take place on the left and right sides respectively, with both operating at the same time, breaking down the whole into its parts and perceiving the parts.

8- **Engagement of conscious and unconscious processes**: Learning requires attention and peripheral awareness, and the brain combines global and fragmented perceptions into a complete recall.

- **Human memory is divided into two main types:** explicit memory and implicit memory, both of which are long-term memory.
  - **Explicit memory**: It involves conscious and intentional recall of information, experiences, and previous concepts.
  - **Implicit memory:** It refers to unconscious memory, which includes acquired knowledge and skills that are acquired unconsciously and used in unconscious processes.

9- Memory approaches: Explicit, semantic, and emotional memory types are influenced by sensory, cognitive, and emotional experiences during learning.

10- **Learning as a developmental process**: involves the gradual development of the brain, an increase in the number of neural connections and acquired experiences that increase the brain's ability to learn. Despite extraordinary cognitive abilities, people often use only a fraction of their brain's potential.
11- **Complex Learning and Emotional State**: Optimal learning occurs in a state of relaxed alertness, combining low threat and high challenge. Threats and fear-related stress hinder learning, while positive emotions enhance it (Abu Al-Saud, 2013; Caine and Caine, 2014).
12- **Unique brain organization**: Each person's brain is organized in a unique way, which is influenced by environmental and genetic factors. Neural connections vary depending on subjective experiences and knowledge, supporting the theory of multiple intelligences (Lucas, 2008).

People are similar and different. For example, each person has their own unique DNA. However, each person has a separate genetic blueprint. Each person has unique life experiences and encounters that are different from others and are influenced by social, economic, and various other factors.
Scientists believe that all of these principles directly enhance the brain's ability to learn optimally. When these principles are combined, they work together to create a positive and effective learning environment. Given the interconnectedness of the fields of science and psychology, as the psychological environment improves, motivation to learn increases and cognitive abilities and thinking skills develop beyond a single lesson.

There are many factors that influence brain-based learning, and the conditions surrounding a student can influence their mental activity, becoming an integral part of their lifestyle and influencing their thinking style and approach. Al-Salti (2004) summarized these factors as follows:

1- **Biological factor**: This type of learning should be incorporated in the classroom and teachers should explore the best ways to develop students' brains towards achieving specific goals. This requires teachers to have knowledge and awareness of the structure and function of the brain.
2- **Genetic factor**: Genetics and inherited traits play a key role in brain capabilities.
3- **Emotional factor**: Emotional experiences, including intense emotions, can affect brain functioning such as an individual's ability to concentrate, pay attention, remember, and think. The impact can be positive or negative.
4- **Environmental Factor**: The environment influences the brain because the brain adapts and changes its structure and function in response to environmental stimuli and external experiences.
5- **Sensorimotor Factor**: The brain receives information through the senses, and proper functioning of the senses allows accurate information to reach the brain to produce natural learning patterns.
6- **Nutritional factor**: Like any organ, the brain requires an adequate supply of nutrients, especially in terms of essential vitamins.

These factors collectively shape brain-based learning and highlight the importance of considering various influences on the brain's optimal learning capabilities.

Methodology and Procedures

The study adopted an experimental methodology, using a quasi-experimental design to examine the effects of brain-based learning strategies on improving academic achievement levels among tenth-grade biological science students. This design was selected because it is consistent with the goals of the current study and provides scientific accuracy, leading to results that can be relied upon to answer the research questions. The study participants were divided into two groups and their assignment was random. One group represented the experimental group that implemented a brain-based instructional strategy, while the other group served as a control group that learned through a conventional instructional strategy.
48 tenth-grade students studying biological sciences took part in the study. The Latin Patriarchate School (Coeducational) was deliberately selected for the study because the teachers and school administration expressed their willingness to cooperate with the researcher. Furthermore, the school's coeducational nature was a requirement to examine the interaction between gender and teaching strategy. The students were divided into two classes and the assignment of classes was random. One class represented an experimental group that learned using brain-based learning strategies and consisted of 24 students. The second class represented the control group that learned according to the conventional teaching strategy and consisted of 24 students. Therefore, the total number of students in both groups was 48. This information is illustrated in table (1).

Table (1): Distribution of Study Participants by Method and Gender Variables

Group	Males	Females	Total
Experimental	13	11	24
Control	11	13	24
Total	24	24	48

The table shows the distribution of study participants according to variable methods (experimental or control) and gender. The experimental group consisted of 12 men and 12 women, while the control group also consisted of 12 men and 12 women. The total number of participants in each group was 24 people.

Study Instruments

To accomplish the goals of this study, the researchers developed a single instrument known as the "Academic Achievement Test." The instrument is presented as follows:

Academic Achievement Test

Scientists have developed a test to measure academic achievement in science, with a focus on biological classification. The test assesses the level of achievement of tenth grade students in science and covers four levels: recall, comprehension, application, and higher order thinking skills (analysis). Multiple-choice questions were selected for the test, and its initial form consisted of 28 questions.

Psychometric Properties of the Test

To ensure the validity of the test content, the original form of the Science Achievement Test was reviewed by 15 experts, including experienced biology teachers, biology teaching supervisors in schools, and professors at Jordanian universities specializing in curricula and teaching methods, educational psychology, measurement, and assessment. This was intended to ensure scientific validity, consistency of test questions with scientific context, linguistic accuracy, clarity of expressions used, appropriateness of the test level for tenth grade students, variety of levels to account for individual differences, suitability of options and alternatives, and alignment of questions with the goals of the study. The feedback from experts was considered, and the questions were modified accordingly. The final form of the Academic Achievement Test, as shown in Appendix 6, consists of 32 items carrying a total score of 32 points.

Reliability of the Academic Achievement Test

To ensure the validity of the academic achievement test, the test was conducted on a pilot sample of 24 tenth-grade male and female students from the Latin Patriarchate schools in Jabal Amman who were not participants in the study. Internal consistency test reliability was calculated using Cronbach's alpha, and test-retest reliability was calculated at a two-week interval. Table 4 shows the reliability coefficients of the Academic Achievement Test.

Table 4. Reliability Coefficients of the Achievement Test

Skill	Internal Consistency Reliability	Test-Retest Reliability
Overall Academic Achievement Test	0.758	0.913
Retrieval	0.734	0.894
Comprehension	0.701	0.876
Application	0.724	0.903
Higher Order Thinking (Analysis)	0.678	0.857

Table 4 shows that the internal consistency reliability values ranged from 0.678 to 0.758, and the test-retest reliabilities ranged from 0.857 to 0.913. The overall internal reliability of the Academic Achievement Test, calculated using Cronbach's alpha, was 0.758, and the overall test-retest reliability was 0.913. Both Cronbach (1984) and Anastasi (1988) consider these values acceptable for this study.

Difficulty and Discrimination Indices of Items

To check the indicators of difficulty and discrimination of subjects, the test was conducted on a sample consisting of (24) male and female tenth grade students, selected from outside the research sample and from the community of schools of the Latin Patriarchate - Al-Jubeiha. Table 5 illustrates the indicators of difficulty and discrimination.

Table (5): Difficulty and Discrimination Indices of the Academic Achievement Test

Question Number	Difficulty Index	Discrimination Index	Question Number	Difficulty Index	Discrimination Index	Question Number	Difficulty Index	Discrimination Index
1	.50	.41	12	.58	.51	23	.58	.71
2	.63	.31	13	.50	.31	24	.67	.36
3	.58	.45	14	.58	.40	25	.83	.92
4	.67	.26	15	.50	.56	26	.79	.52
5	.33	.61	16	.38	.36	27	.63	.67
6	.79	.73	17	.54	.50	28	.63	.67
7	.58	.38	18	.46	.57	29	.54	.44
8	.50	.42	19	.46	.41	30	.38	.57
9	.54	.42	20	.50	.78	31	.33	.53
10	.46	.72	21	.50	.46	32	.42	.69
11	.50	.39	22	.38	.61			

Table (5) shows that the question difficulty indices ranged from 0.33 to 0.79, and the discrimination indices ranged from 0.31 to 0.92. This means the test considers individual differences between students and has good indicators of difficulty and discrimination.

Test Correction

The test consists of 32 questions, and each student receives one point for each correct answer and zero for each incorrect answer. Since the test consists of 32 items, the possible range of test scores is from 0 to 32.
To determine the appropriate time to administer an achievement test to a sample of 24 students, the average time it took the first 5 students and the last 5 students to complete the test was calculated. The average time it took the first 5 students to complete the test was X minutes, while the average time it took the last 5 students to do the same was Y minutes (41 minutes total).

Statistical Analysis

To answer the research questions, the SPSS software is used by the researcher as follows:
For addressing the first research question, the mean scores, and standard deviations of students' answers on the achievement test were calculated**.** The ANCOVA test and MANCOVA test were used as a measure to test the data.
For addressing the second research question, from the scores that students got on the achievement test, the researcher computed the mean scores and standard deviations. Using the two-way analysis of covariance (2-way ANCOVA) test, the data was analyzed. The multivariate analysis of covariance (MANCOVA) test was also conducted.
These statistical techniques were used to determine the relationship between brain-based learning teaching strategies and students' academic performance in science. SPSS software facilitated data analysis and provided statistical insights to draw meaningful conclusions from the study.

Results

First: Results Related to Research Question 1:

The research question is: "Are there statistically significant differences, at the α=0.05 significance level, between the study groups' mean scores on the comprehensive and detailed posttest assigned to the instructional strategy (brain-based learning strategy vs. conventional strategy)?"

The difference in the overall test score

To answer this question, the arithmetic means, and standard deviations were extracted for the pre-test and post-test measurements of both the experimental and control groups on the achievement test. The results are presented in Table (19) as follows:

Table 19. Mean and Standard Deviation of Pretest and Posttest Measures for the Experimental and Control Groups on the Achievement Test.

Group	**Pretest**		**Posttest**	
Mean Standard	Deviation Mean	Standard Deviation	Deviation Mean	Standard Deviation
Experimental	17.13	5.705	27.29	3.770
Control	18.00	4.324	20.96	4.592
Total	17.56	5.027	24.13	5.246

The results of table (19) indicate a statistically significant difference between the means of both experimental and control groups in the achievement test posttest scores in favor of the experimental group that is assigned to be taught using a brain-based teaching strategy. The mean score of the experimental group that was exposed to the instructional strategy on the posttest measurement of the achievement test was 27.29, while the mean score of the control group on the posttest measurement of the achievement test was 20.96. To determine whether this difference was statistically significant, the ANCOVA test was used. The results are presented in table (20).

Table 20. Results of the ANCOVA test for the difference between the two groups on the achievement test.

Source of Variation	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	**F value**	**Significance Level**	**Eta Squared Effect Size**
Pre	86.406	1	86.406	5.359	.025	.106
Group	514.011	1	514.011	31.882	.000	.415
Error	725.510	45	16.122			
Total	1293.250	47				

Table (20) shows a statistically significant difference at the α = 0.05 significance level between study participants' mean scores on posttest scores assigned to the teaching strategy. The experimental group instructed with the brain-based learning strategy achieved a significantly higher mean score than the control group. This is indicated by the F value (31.882) and effect size (η2) of the teaching strategy on academic achievement, which accounted for 41.5% of the variance. These findings suggest a significant impact of teaching strategies. Table (21) shows the adjusted means and standard errors for the experimental and control groups on the achievement test.

Table 21. Adjusted Means and Standard Errors for the Experimental and Control Groups on the Achievement Test

Group	Adjusted Mean	Standard Error
Experimental	27.410	0.821
Control	20.840	0.821

Note: The table shows the adjusted means and standard errors of achievement tests for the experimental and control groups. The adjusted mean represents the mean score for each group, and the standard error represents the variability around the mean.

Differences in Subtest Scores

The mean scores and standard deviations of pre- and post-test measurements of subjects in the experimental and control groups on the subtests of the achievement test were calculated. The results are presented in table (22).

Table 22. Mean Scores and Standard Deviations of Pre-test and Post-test Measurements for the Experimental and Control Groups on Subtests of the Achievement Test

Group		Experimental		Control	
		Mean	Standard Deviation	Mean	Standard Deviation
Pre-test	Recall	6.50	2.485	7.38	2.242
	Comprehension	4.67	1.880	5.08	1.717
	Application	4.04	1.367	3.25	1.511
	Analysis	1.92	1.248	2.29	.999
Post-test	Recall	10.00	1.694	8.17	2.180
	Comprehension	7.21	1.285	5.79	1.414
	Application	6.21	1.474	4.54	1.587
	Analysis	3.88	.850	2.46	.977

Table (22) shows that there are statistically significant differences between the means of both experimental and control groups in post-test scores in the subdomains of the achievement test in favor of the experimental group. These differences can be attributed to teaching strategies. To determine whether these differences were statistically significant, a MANCOVA test was performed. The results of this test are shown in table (23).

Table 23. MANCOVA Test Results for the Significance of Differences between the Groups on the Achievement Test

Source of Variation	Subdomains	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level	Eta Squared Effect Size
Pretest (within-groups)	Recall	.261	1	.261	.067	.796	.002
	Comprehension	2.210	1	2.210	1.148	.290	.027
	Application	1.428	1	1.428	.767	.386	.018
	Analysis	1.922	1	1.922	2.292	.137	.052
Hotelling's T-squared value = .997 Significance level = .000	Recall	33.532	1	33.532	8.663	.005	.171
	Comprehension	21.857	1	21.857	11.356	.002	.213
	Application	31.384	1	31.384	16.850	.000	.286
	Analysis	21.042	1	21.042	25.094	.000	.374
Error	Recall	162.577	42	3.871			
	Comprehension	80.833	42	1.925			
	Application	78.228	42	1.863			
	Analysis	35.218	42	.839			
Total	Recall	215.667	47				
	Comprehension	108.000	47				
	Application	141.250	47				
	Analysis	62.667	47				

Table (23) shows that there are statistically significant differences at the significance level (α = 0.05) between the means of the experimental and control groups in all areas of the achievement test (recall, understanding, application, analysis). These differences are attributed to the teaching strategy preferred by the experimental group, which was taught using a brain-based learning instructional strategy. The calculated "F" values were statistically significant at the 0.05 level of significance. Notably, the effect size was largest in the analysis domain, with an eta-squared value of 0.374, followed by the application domain, with an eta-squared value of 0.286. Next is the comprehension domain with an eta-squared of 0.213, and finally the recall domain with an eta-squared of 0.171. The Hotelling value was 997, indicating statistical significance with a p-value of 0.000. Table (24) shows the adjusted means and standard errors for the experimental and control groups in the achievement test domains.

Table 24. Adjusted Means and Standard Errors for the Experimental and Control Groups According to Subdomains of the Achievement Test

Subdomains	Group	Adjusted Mean	Standard Error
Recall	Experimental	10.035	.430
	Control	8.132	.430
Comprehension	Experimental	7.268	.303
	Control	5.732	.303
Application	Experimental	6.296	.299
	Control	4.454	.299
Analysis	Experimental	3.921	.200
	Control	2.413	.200

Secondly, the results related to the second question are as follows:

Question Text: Are there statistically significant differences at the level of significance (α=0.05) between study groups' mean scores on the general achievement test and domain-specific scores attributable to the interaction of gender and teaching strategy (brain-based teaching strategy and conventional teaching strategy)?

The differences in the overall scores of the test

To answer this question, mean scores and standard deviations were calculated for the pre- and post-test measures of the experimental group (male, female) and control group (male, female) based on gender for the achievement test. The results are presented in table (25).

Table 25. Mean scores and standard deviations of pretest and posttest measures for participants in the experimental and control groups, according to gender (males, females), on the achievement test

Group	Gender	Number	Pre-test		Post-test	
			Mean	Standard Deviation	Mean	Standard Deviation
Experimental	Female	11	17.18	5.724	28.36	3.171
	Male	13	17.08	5.923	26.38	4.114
	Total	24	17.13	5.705	27.29	3.770
Control	Female	13	18.54	4.484	21.38	4.073
	Male	11	17.36	4.249	20.45	5.298
	Total	24	18.00	4.324	20.96	4.592
Total	Female	24	17.92	5.021	24.58	5.064
	Male	24	17.21	5.116	23.67	5.490
	Total	48	17.56	5.027	24.13	5.246

Table (25) shows a statistically significant difference in the means of both experimental and control groups in the achievement test posttest in favor of the experimental group, attributed to the interaction of gender and teaching strategy. To determine whether this difference was statistically significant, a “2-way ANCOVA” test was used and the results are presented in table (26).

Table 26. Results of the "2 Way ANCOVA" test indicating the significance of the differences between the two groups on the achievement test

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Value	Significance Level	Eta-Squared Effect Size
SS Pre	82.845	1	82.845	5.085	.029	.106
SS Group	527.039	1	527.039	32.348	.000	.429
SS Gender	19.574	1	19.574	1.201	.279	.027
SS Group * Gender	5.283	1	5.283	.324	.572	.007
SS Error	700.582	43	16.293			
SS Total	1293.250	47				

*Note: "SS" stands for "Sum of Squares," which measures the total variability or dispersion within a dataset by summing the squared differences between each data point and the mean.

Table (26) shows a statistically significant difference at the level of significance (α = 0.05) between the mean scores of the study groups in the final test, attributed to the teaching strategy, in favor of the experimental group instructed using the brain learning teaching strategy method. This is indicated by the obtained "F" value (32.348) and effect size (η2) for the brain-based teaching strategy on the achievement test (42.9%), which indicates a significant impact of the teaching strategy.

There was no statistically significant difference at the level of significance (α = 0.05) between the study groups' mean scores on the gender-attributed final test or the interaction of gender with teaching strategy. This is indicated by the obtained "F" values (1.201 and 0.3240), and table (27) presents the adjusted means and standard errors for the experimental and control groups in the achievement test.

Table 27. Adjusted Means and Standard Errors for the Experimental and Control Groups on the Achievement Test

Group	Adjusted Mean	Standard Error
Experimental	27.410	0.821
Control	20.840	0.821

Differences on Test Domains

Arithmetic means and standard deviations of pre- and post-test measurements of participants in the experimental and control groups were calculated, by gender, in the areas of the achievement test. The results are presented in Table (28).

Table 28. Arithmetic means and standard deviations for the pre-test and post-test measurements of the participants in the experimental and control groups, according to gender, on the domains of the achievement test

Group	Gender	Test	Pre-test				Post-test			
			Retrieval	Comprehension	Application	Analysis	Retrieval	Comprehension	Application	Analysis
Experimental	Male	Mean	6.27	4.82	4.09	2.00	10.27	7.82	6.55	3.73
		SD	2.328	1.991	1.300	1.265	1.421	.982	1.508	.905
	Female	Mean	6.69	4.54	4.00	1.85	9.77	6.69	5.92	4.00
		SD	2.689	1.854	1.472	1.281	1.922	1.316	1.441	.816
	Total	Mean	6.50	4.67	4.04	1.92	10.00	7.21	6.21	3.88
		SD	2.485	1.880	1.367	1.248	1.694	1.285	1.474	.850
Control	Male	Mean	7.77	5.08	3.15	2.54	8.23	6.08	4.62	2.46
		SD	2.242	1.847	1.405	.776	2.166	.862	1.609	.877
	Female	Mean	6.91	5.09	3.36	2.00	8.09	5.45	4.45	2.45
		SD	2.256	1.640	1.690	1.183	2.300	1.864	1.635	1.128
	Total	Mean	7.38	5.08	3.25	2.29	8.17	5.79	4.54	2.46
		SD	2.242	1.717	1.511	.999	2.180	1.414	1.587	.977
Total	Male	Mean	7.08	4.96	3.58	2.29	9.17	6.88	5.50	3.04
		SD	2.358	1.876	1.412	1.042	2.099	1.262	1.818	1.083
	Female	Mean	6.79	4.79	3.71	1.92	9.00	6.13	5.25	3.29
		SD	2.449	1.744	1.574	1.213	2.226	1.676	1.675	1.233
	Total	Mean	6.94	4.88	3.65	2.10	9.08	6.50	5.38	3.17
		SD	2.383	1.794	1.480	1.134	2.142	1.516	1.734	1.155

*Note: The abbreviation "SD" stands for Standard Deviation.

Table (28) shows that there are significant differences in the mean scores between both groups, experimental and control, in the post-test of the achievement test in favor of the experimental group. These differences are attributed to the interaction of gender and teaching strategies. The "MANCOVA" test was used to determine the statistical significance of these differences. The results of this test are presented in Table (29).

Table 29. Results of "MANCOVA" test for the significance of differences between the two groups on the achievement test

Source of Variation	Subdomains	Sum of Squares	Degrees of Freedom	Mean Squares	F Value	Significance Level	Eta-Squared Effect Size
Pre (Common)	Retrieval	.429	1	.429	.106	.746	.003
	Comprehension	1.757	1	1.757	.979	.329	.024
	Application	1.259	1	1.259	.666	.419	.016
	Analysis	2.096	1	2.096	2.427	.127	.057
Group Hotelling's T2 Value = 1.007 Statistical Significance = .000	Retrieval	34.217	1	34.217	8.485	.006	.175
	Comprehension	22.687	1	22.687	12.637	.001	.240
	Application	32.446	1	32.446	17.168	.000	.300
	Analysis	20.587	1	20.587	23.837	.000	.373
Gender Hotelling's T2 Value = .147 Statistical Significance = .268	Retrieval	.433	1	.433	.107	.745	.003
	Comprehension	8.455	1	8.455	4.709	.056	.051
	Application	.694	1	.694	.367	.548	.009
	Analysis	.511	1	.511	.592	.446	.015
Group * Gender Hotelling's T2 Value = .033 Statistical Significance = .873	Retrieval	.820	1	.820	.203	.654	.005
	Comprehension	.479	1	.479	.267	.608	.007
	Application	1.889	1	1.889	.999	.323	.024
	Analysis	.149	1	.149	.173	.680	.004
Error	Retrieval	161.298	40	4.032			
	Comprehension	71.809	40	1.795			
	Application	75.595	40	1.890			
	Analysis	34.545	40	.864			
Total	Retrieval	215.667	47				
	Comprehension	108.000	47				
	Application	141.250	47				
	Analysis	62.667	47				

Table (29) shows statistically significant differences at the level of significance between the mean scores of both experimental and control groups, in all areas of the achievement test (Research, Comprehension, Application, Analysis), assigned to the teaching strategy in favor of the experimental group that was taught using the strategy brain-based learning. The "F" values were statistically significant at a significance level of 0.05, with a Hotelling T2 value of 1.007 and a statistical significance of 0.0000.
There were no statistically significant differences at the level of significance (α = 0.05) between the mean scores of both experimental and control groups in all areas of the achievement test (Recovery, Comprehension, Application, Analysis), attributed to gender or the interaction between gender and teaching strategy. The "F" values were not statistically significant at the 0.05 significance level, with a Hotelling T2 value of 0.033 and a statistical significance of 0.873 for the group-sex interaction. Table (30) shows the adjusted means and standard errors for the experimental and control groups in all areas of the achievement test.

Table 30. Mean scores and standard errors for the experimental and control groups on the achievement test

Academic domains	Group	Adjusted Mean	Standard error
Retrieval	Experimental	10.058	.442
	Control	8.131	.439
Comprehension	Experimental	7.293	.295
	Control	5.724	.293
Application	Experimental	6.330	.302
	Control	4.454	.301
Analysis	Experimental	3.909	.204
	Control	2.414	.203

Results Discussion and Recommendations

Discussion of the results related to academic achievement levels:
Discussion of the results of the first question

The results of the statistical analysis showed statistically significant differences between the mean scores of the experimental and control groups in terms of the level of academic achievement after the test. These differences favored the experimental group, which was taught using a brain-based learning strategy. These findings suggest the effectiveness of this teaching strategy in increasing levels of academic achievement. The experimental group's mean score on the post-test was 27.29, while the control group's mean score on the same test was 20.96. This indicates the impact of brain-based learning strategies on improving academic achievement levels, and the size of this impact was significant. The learning process using brain-based learning strategies produced relatively satisfactory results.
The researchers attribute this to the way the strategy captures the learner's attention by evoking positive emotions, which the principles of brain-based learning refer to as "emotions are critical and necessary for pattern formation." Emotions have a positive impact on an individual's practical life because they provide a sense of security and inner happiness that the brain participates in the patterning process. They also stimulate the hormones of happiness and inner satisfaction, which help reduce threats, fears, challenges, and internal arousal of the student (Caine and Caine, 2014). Emotions play a key role in meaning creation (Caine and Caine, 1990), and the limbic system, historically known as the “emotional brain,” regulates emotion and affect, in addition to the prefrontal cortex (OECD, 2007). However, brain research has shown that our limbic system is also related to learning and memory (Hill, 2001), and emotions help facilitate the storage and retrieval of information (Rosenfield, 1988). Moreover, in terms of brain neural plasticity, our emotions contribute to the development of stronger neural networks, which our brain learns when "emotional chemicals" such as adrenaline, serotonin, and dopamine modify synaptic connections. Therefore, neural changes are most pervasive and powerful when emotions are part of the learning process (Zull, 2005).
According to Robert Sylwester, as cited by the research of McGuckin and Ladhani (2010) and the research of D'Arcangelo (1998), the attention system in the brain is controlled by the emotional system, which naturally drives the process of learning, remembering and all other brain processes. From a biological point of view, it is impossible to learn or remember anything that does not interest us. Emotional arousal can hinder or enhance the learning process.
And because the brain-based learning strategy is based on continuous assessment and providing feedback to the student in three forms: diagnostic, formative and summative, it provides the student with feedback through continuous assessment by verifying the accuracy of the information and the strength of its connections by engaging students in answering questions and interactive tasks that range from short answer to collaborative or collaborative tasks. In addition, it provides direct and indirect feedback and corrective measures in the teaching process and tracks academic development by recording strengths and weaknesses for feedback through formative and final assessments.
One of the cornerstones of brain-based learning strategies is feedback, which is considered a valuable source for the learner, especially if it comes from peers rather than an authoritative figure (McGuckin and Ladhani, 2010). Additionally, the constant presence of a teacher who immediately corrects scientific errors in case of scientific errors reinforces the learning process in the right way.
It may be that the use of open-ended questions at the beginning of each session helped to increase the level of academic achievement under the brain-based learning strategy. Open-ended questions with multiple answers activate students' prior experiences. This type of questioning builds self-confidence and increases curiosity in learning. These questions correspond to the levels of Bloom's taxonomy (knowledge, understanding, application, analysis, synthesis, evaluation). The true value of these questions lies not only in confirming the existence of knowledge, but also in stimulating students' motivation, developing their love of inquiry, and promoting the willingness to learn and participate in the educational process in the classroom environment. Moreover, open-ended questions attract students' attention, reduce distractions and develop their cognitive thinking skills. For educators, their importance lies in observing students' strengths and weaknesses, monitoring individual differences, ensuring transparency and reception of information in students' minds, shaping their cognitive attitudes and interests, and paying attention to shy students who may hesitate to ask for certain information (Ministry of Education Ontario, 2011).
The results can be attributed to the strategy, which incorporates collaborative group activities as a key learning method. Studies such as Baser and Durmus (2010) and Özgelen (2012), cited by Hernawati et al. (2018) emphasize that learning through such activities, including scientific inquiry skills, is essential. Engaging in these activities develops critical thinking, supporting students in achieving their academic goals. Scientific inquiry skills have been linked to better cognitive abilities that promote thinking, reasoning and problem solving. It is worth noting that there is a significant relationship between students' academic skills and academic achievement levels, as indicated in previous studies.
The results of this study are consistent with previous studies such as Al-Mashaqbeh (2017), Al-Quraira (2018), Hamdoun (2019), Al-Shabatat (2015), Al-Titi (2014), Al-Abbasi (2010), and Al-Jurani (2008) (note that no specific sources are provided).

Moreover, studies conducted by Annakoda (2015), Duman (2013), and Riasat and Shahz (2010) also found comparable results.
These studies have demonstrated the positive impact of brain-based learning strategies on increasing academic achievement levels in science.
Discussion of the results of the second question, which stated: Are there statistically significant differences at the level (α = 0.05) between the average results of the study groups in the general and specific academic achievement test, attributed to the interaction of gender and teaching strategy (brain-based learning strategy and conventional strategy)?
The results showed no statistically significant difference between the mean scores of the study groups on the General Academic Achievement Test and at each level of academic achievement attributed to the interaction of gender and teaching strategy. This means that the brain-based learning strategy is suitable for both genders, without any specific preference. The lack of interactions between gender variables and teaching strategy suggests that the strategy applies to both genders in teaching levels of academic achievement. Moreover, the brain-based learning strategy improved academic achievement levels in men and women equally. This means that the level of teaching and increasing the level of academic achievement can be achieved regardless of gender.
The lack of interaction may be attributable to the equivalence of the male and female study groups in terms of prior experiences and exposure to similar teaching conditions, including the classroom environment, instructional materials, and accompanying learning activities during the study. Also, there may be similarities in economic and social conditions and age levels between the genders. A study by Lucas (2008) mentioned that each human brain, whether male or female, is uniquely organized and influenced by numerous factors, including genetic and environmental influences. Connections between brain cells are formed by cognitive, personal, and social experiences. Memory or the level of recall depends on three main elements: relevance to the recipient, meaning, and time and place (Caine and Caine, 2014). Learning requires attention and perception, with emphasis on key stimuli that have great meaning and importance to brain receptors. Therefore, one gender does not influence the other.
The results of this study are consistent with those of Annakoda (2015), Erol and Karaduman (2018), and Shahzad, Ghazi, and Riasat (2010). They are also consistent with writings on brain function, mechanisms, principles, and important teaching strategies that are consistent with brain function.

Recommendations and Suggestions

Based on the findings of the current study, the following recommendations and suggestions can be made:

- Direct teacher preparation curriculum and textbook developers to activate practice skills to improve academic achievement by adopting brain-based learning strategies in academic and professional biology teacher preparation courses.
- Implement brain-based activities over a long time to assess their impact on students' biology approach.
- Conduct a comparative study between teaching using a brain-based learning strategy and other teaching strategies.
- Conducting further research into effective, modern, science-based strategies for primary school students that can effectively improve academic achievement.
- Encouraging collaboration and teamwork among teachers in teacher preparation programs, enabling them to exchange ideas and experiences in implementing brain-based learning strategies and developing effective teaching skills.

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