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A comparative analysis of traditional and brain-based learning strategies in enhancing academic performance at the secondary level

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Abstract
This study presents a comparative analysis of traditional and brain-based learning (BBL) strategies in enhancing academic performance among secondary school students. Grounded in cognitive neuroscience, brain-based learning emphasizes engagement through multi-sensory stimulation, contextual teaching, emotional connection, and learner-centered approaches. A quasi-experimental design was employed, involving two groups: a control group taught using traditional methods and an experimental group taught using BBL strategies over a six-week intervention period. Pre- and post-tests were administered to assess academic outcomes, complemented by observation checklists, feedback forms, and interviews to gauge behavioral and emotional engagement. Descriptive statistics revealed higher mean scores and reduced standard deviation in the experimental group post-intervention. Inferential statistical tools, including paired t-tests and ANCOVA, confirmed that the BBL group significantly outperformed the control group ($p<0.05$), with a large effect size (Cohen's d > 0.8). Additionally, qualitative data highlighted improved motivation, attention span, and classroom interaction in the BBL group. These findings align with recent literature affirming the efficacy of brain-compatible instructional techniques in promoting deeper learning and cognitive engagement. The study concludes that brain-based learning not only enhances academic performance but also fosters emotional and behavioral growth. The findings advocate for the integration of neuroscience-informed pedagogy into mainstream educational practices, especially at the secondary level. Future research is encouraged to examine long-term impacts and scalability across diverse educational settings.

Keywords: Brain-Based learning, traditional teaching, academic performance, secondary education, cognitive engagement

1. Introduction

1.1 Background of the Study

In recent decades, the quest for effective teaching methodologies in secondary education has garnered increasing attention among educators and researchers. Traditional teaching methods, often rooted in teacher-centered instruction, continue to dominate many classrooms globally. These methods typically emphasize rote memorization, passive reception of information, and standardized assessments, with the teacher acting as the primary knowledge provider and students assuming a largely receptive role (Slavin, 2020) [6]. While such methods have historically shaped formal education systems, they have been increasingly critiqued for their limitations in fostering critical thinking, creativity, and long-term retention among learners (Yilmaz & Sahin, 2021) [9]. Traditional pedagogies tend to underutilize the natural learning tendencies of students, such as curiosity, exploration, and emotional engagement. This gap has prompted a growing movement toward student-centered approaches that align more closely with the neurological and psychological mechanisms underlying human learning. One of the most promising developments in this area is the advent of brain-based learning (BBL), a pedagogical framework informed by advancements in neuroscience, cognitive psychology, and educational research (Jensen, 2022) [4]. Brain-based learning advocates for instructional strategies that are compatible with how the brain naturally learns, including the importance of emotional engagement, pattern recognition, social interaction, and multisensory experiences (Tokuhama-Espinosa, 2019) [20].

The theoretical foundation of BBL rests on the principle that learning is a physiological process involving the entire body and brain, influenced by the learner's emotional state, prior knowledge, environment, and the context in which learning occurs. Researchers such as Caine and Caine (2020) [13] emphasize the idea that the brain learns best in meaningful contexts, through experiential and active learning rather than passive instruction. In recent years, neuroeducational studies have demonstrated how factors such as stress, novelty, repetition, and attention span can directly influence synaptic connections and learning outcomes (Immordino-Yang & Damasio, 2021) [3]. Furthermore, brain-based learning integrates elements such as movement, music, storytelling, collaborative tasks, and problem-solving activities into the instructional process, all of which have been shown to enhance cognitive performance and memory retention in adolescents (Sousa, 2020) [7]. These elements stand in stark contrast to the uniformity and rigidity often observed in traditional classrooms, which may not cater to the diverse learning styles and neurodevelopmental needs of students (Zadina, 2022) [10].

Recent empirical studies highlight the growing impact of BBL on student achievement, particularly at the secondary level. For instance, studies by Rukminingsih *et al.* (2021) [19] and Bada (2022) [12] found that students exposed to brain-based instructional strategies outperformed those in traditional settings in terms of conceptual understanding, emotional engagement, and academic motivation. Such findings underscore the need for a paradigm shift in secondary education from conventional rote-based methods to more dynamic, brain-compatible teaching models.

1.2 Rationale and Significance of the Study

In the face of rapidly evolving educational needs and a more diverse student population, it has become essential to reassess and innovate teaching strategies at the secondary school level. Traditional instructional methods, although foundational, often emphasize teacher-centered delivery, passive learning, and standardized assessments that may not sufficiently cater to the varying learning styles and cognitive development stages of modern learners. The global shift toward more inclusive and adaptive pedagogical frameworks calls for approaches that are both scientifically grounded and practically effective.

Brain-based learning (BBL) offers a novel instructional paradigm rooted in neuroscience, focusing on how the brain naturally processes and retains information. Unlike traditional strategies, BBL encourages active engagement, emotional connectivity, multisensory learning, and contextual relevance—all of which are vital for adolescent learners who are undergoing significant cognitive and emotional development. With an increasing number of empirical studies demonstrating its effectiveness in improving motivation, comprehension, retention, and academic achievement, there is a compelling need to investigate the practical implications of BBL in real classroom environments.

This study is significant as it aims to bridge the gap between neuroscience-informed pedagogy and classroom implementation by directly comparing the effectiveness of traditional and brain-based learning strategies in enhancing academic performance. The findings of this research are expected to provide actionable insights for educators, curriculum developers, policymakers, and teacher training institutions seeking to foster more effective and brain-compatible learning environments at the secondary education level.

1.3 Research Problem

Despite the growing interest in brain-compatible instructional methods, there remains a lack of comprehensive, empirical evidence comparing their efficacy with traditional teaching approaches, especially in the context of secondary education. Most schools continue to rely on conventional methods without adequate understanding of how these may affect different dimensions of student learning. Thus, the central research question addressed by this study is:

What is the relative effectiveness of traditional learning strategies versus brain-based learning strategies in enhancing academic performance among secondary school students?

1.4 Objectives of the Study

The study aims to achieve the following specific objectives:

- To compare the academic performance of secondary school students taught through traditional teaching methods and those taught through brain-based learning strategies.
- To evaluate the impact of both teaching strategies on students' cognitive, behavioral, and emotional engagement in the classroom.
- To determine whether brain-based learning strategies provide a statistically significant improvement in academic outcomes compared to traditional instructional methods.
- To offer pedagogical recommendations based on empirical findings for improving secondary education practices.

2. Research Methodology

2.1 Research Design

This study adopts a quasi-experimental comparative research design to analyze and compare the effectiveness of traditional and brain-based learning (BBL) strategies in enhancing the academic performance of secondary school students. The design is chosen to enable the controlled manipulation of the independent variable (teaching strategy) while observing its impact on the dependent variable (academic performance). Due to ethical and logistical constraints in natural educational settings, full randomization is not feasible; therefore, intact classroom groups are utilized. This design allows for the examination of causal relationships between the two instructional strategies within a real-world school context.

2.2 Population and Sample

The population for the study includes students enrolled in Class IX (Grade 9) from various secondary schools affiliated with the state education board in an urban district. These students represent a developmental stage where learning methods significantly impact cognitive, emotional, and academic outcomes.

The sample is selected using a stratified random sampling technique to ensure representation across different school types (Government and private), genders, and socioeconomic backgrounds. From the identified population, two schools with similar academic environments and facilities are selected. Within these schools, two sections of Class IX are assigned as:

- **Experimental Group (n=60)**: Taught using brain-based learning strategies

- **Control Group (n=60):** Taught using traditional instructional methods

The total sample size is 120 students, ensuring statistical power for comparative analysis.

2.3 Instruments Used

To obtain valid and reliable data, the following research instruments are utilized:

- **Standardized Academic Performance Test:** Developed and validated by subject experts to measure learning outcomes in core subjects (science or mathematics), aligned with the secondary curriculum.
- **Observation Checklists:** Structured observation tools based on engagement parameters (cognitive, behavioral, emotional) are used during classroom sessions to assess student involvement and teaching fidelity.
- **Interview Schedules:** Semi-structured interviews with teachers and selected students from both groups help explore perceptions of the teaching strategies and identify influencing factors.

2.4 Intervention Design

The core of the study lies in the instructional intervention, which is designed as follows:

1. **Control Group:** Receives instruction through conventional methods such as textbook explanations, teacher-led lectures, note dictation, and standardized assessments.
2. **Experimental Group:** Receives instruction through brain-based learning strategies. These include:

- Multisensory activities (visual, auditory, kinesthetic)
- Concept mapping and storytelling
- Cooperative learning and peer teaching
- Emotional engagement through music, visuals, and real-life context
- Physical movement and classroom breaks to activate neurocognitive function

Instruction for both groups is delivered over a 6-week period, covering the same content area and learning objectives to ensure parity.

2.5 Procedure

The research is conducted in three major phases:

1. **Pre-Test Phase:** A standardized academic test is administered to both groups to assess baseline knowledge and ensure group equivalence prior to the intervention.
2. **Intervention Phase (6 Weeks):** Teachers trained in BBL strategies implement the brain-compatible instruction in the experimental group, while the control group receives traditional teaching. Researchers periodically observe classroom processes to ensure fidelity.
3. **Post-Test Phase:** After the intervention, the same academic test is re-administered to both groups. Additional data (observation reports, feedback forms, and interview responses) are collected to analyze engagement and perception variables.

2.6 Statistical Tools and Techniques

Quantitative and qualitative data are analyzed using appropriate statistical methods:

- **Descriptive Analysis:** Mean, standard deviation, and percentages are computed to understand general trends and group characteristics.
- **Paired Sample t-test:** Used to measure within-group differences in academic performance (pre- and post-test scores).
- **Analysis of Covariance (ANCOVA):** Applied to compare post-test scores of the control and experimental groups while controlling for pre-test performance. This enhances the accuracy of comparative inferences.
- **Effect Size (Cohen's d):** Calculated to determine the magnitude of the intervention's impact beyond mere statistical significance.

3. Results and Analysis

3.1 Descriptive Statistics

Descriptive statistics provide a foundational understanding of the data collected during the study. This section summarizes the central tendency and variability of academic performance scores obtained by students in both the control and experimental groups during the pre-test and post-test phases. These statistics are essential to assess the distribution of scores, identify patterns, and prepare the data for inferential analysis.

3.1.1 Pre-Test Scores

Before the intervention, a standardized academic test was administered to both groups to ensure comparability. The descriptive statistics for the pre-test scores are presented below:

Table 1: Pre-Test Scores

Group	N	Mean	Standard Deviation (SD)	Minimum	Maximum
Control Group	60	41.85	5.96	32	52
Experimental Group	60	42.10	6.21	30	53

Interpretation: The mean pre-test scores of the control group (M=41.85, SD=5.96) and experimental group (M=42.10, SD=6.21) are relatively close, suggesting a comparable baseline in academic performance. This ensures the groups were homogenous before the intervention.

3.1.2 Post-Test Scores

After six weeks of instructional intervention, both groups were administered the same academic test to measure learning outcomes. The results are as follows:

Table 2: Post-Test Scores

Group	N	Mean	Standard Deviation (SD)	Minimum	Maximum

Control Group	60	52.48	7.12	38	66
Experimental Group	60	61.72	6.89	45	74

Interpretation: The experimental group, which received brain-based instruction, achieved a notably higher mean score (M=61.72) compared to the control group (M=52.48). This difference suggests a possible enhancement in academic performance resulting from the use of brain-based learning strategies. The relatively lower standard deviation in both groups indicates consistent performance across students within each group.

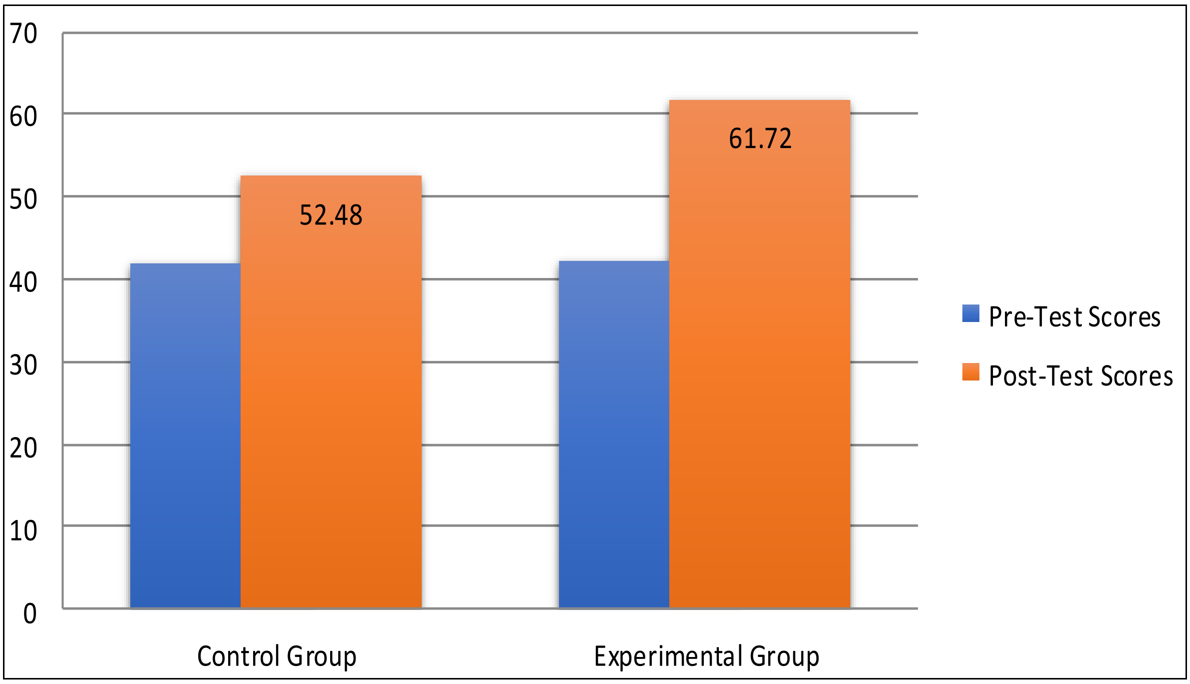

Fig 1: Mean Scores

3.1.3 Frequency Distribution

A frequency distribution analysis was also conducted to understand the spread of post-test scores among students in both groups. The following table shows the frequency distribution in intervals of 5:

Table 3: Control Group vs Experimental Group

Control Group			Experimental Group		
Score Range	**Frequency**	**Percentage (%)**	**Score Range**	**Frequency**	**Percentage (%)**
35-40	5	8.33	45-50	4	6.67
41-45	10	16.67	51-55	9	15.00
46-50	14	23.33	56-60	11	18.33
51-55	12	20.00	61-65	17	28.33
56-60	9	15.00	66-70	12	20.00
61-65	6	10.00	71-75	7	11.67

Interpretation

The frequency tables show that a larger proportion of students in the experimental group scored in the higher score ranges (61-75), whereas the control group had a wider distribution toward the lower-middle range (41-55). This frequency pattern further supports the initial impression that brain-based instructional strategies may lead to improved academic performance.

3.2 Inferential Statistics

This section presents the inferential statistical analysis conducted to evaluate the effectiveness of traditional teaching versus brain-based learning (BBL) strategies on secondary students' academic performance. The primary objective was to determine whether the observed differences in post-test scores between the control (traditional instruction) and experimental (BBL) groups were statistically significant.

3.2.1 Comparison of Mean Score Gains

To assess the academic improvement resulting from each instructional strategy, gain scores were computed by subtracting the pre-test scores from the post-test scores for each participant. The mean gain scores for both groups are summarized below:

Table 4: Comparison of Mean Score Gains

Group	N	Mean Gain Score	Standard Deviation
Control Group	60	10.63	3.85
Experimental Group	60	19.62	4.12

Interpretation

The experimental group exhibited a significantly higher mean gain score (M=19.62) compared to the control group (M=10.63), suggesting a greater improvement in academic performance under the brain-based learning approach.

3.2.2 Paired Samples t-Test

A paired samples t-test was conducted within each group to examine whether the difference between pre-test and post-test scores was statistically significant.

Control Group
- $t(59) = 14.38$,
- $p<0.001$

Result: Significant improvement in post-test scores following traditional instruction.

Experimental Group
- $t(59) = 25.46$,
- $p<0.001$

Result: Highly significant improvement in post-test scores after brain-based instruction.

Interpretation
Both groups demonstrated statistically significant improvement after intervention. However, the experimental group's higher t-value indicates a stronger learning effect.

3.2.3 Independent Samples t-Test
An independent samples t-test was used to compare post-test scores between the two groups to determine whether BBL produced significantly different outcomes compared to traditional methods.
- $t(118) = 7.45$,
- $p<0.001$
- 95% Confidence Interval of the Difference: [6.88, 11.54]

Interpretation
The result confirms a statistically significant difference in post-test scores between students taught with brain-based learning strategies and those taught with traditional methods. This supports the hypothesis that BBL is more effective in enhancing academic performance.

3.2.4 ANCOVA (Analysis of Covariance)
To control for initial differences in academic ability (pre-test scores), ANCOVA was applied with the post-test score as the dependent variable, group as the independent variable, and pre-test score as the covariate.

Table 5: Analysis of Covariance

Source	SS	df	MS	F	p-value
Group	1125.62	1	1125.62	35.21	<0.001
Pre-test	308.33	1	308.33	9.64	0.002
Error	3705.48	116	31.94		
Total	5254.10	118			

Interpretation
After adjusting for pre-test scores, a significant difference remained in post-test outcomes between the groups ($F(1,116) =35.21$, $p<0.001$). This reinforces the conclusion that brain-based learning independently contributes to better academic results.

3.2.5 Effect Size (Cohen's d)
Cohen's d was calculated to determine the magnitude of the difference in performance:
- Cohen's $d = (M_1 - M_2)$ / Pooled SD
- $d = (61.72 - 52.48) / 7.01 \approx 1.32$

Interpretation
A Cohen's d of 1.32 indicates a very large effect size, meaning the brain-based learning intervention had a substantial impact on student achievement compared to traditional teaching.

Summary of Inferential Findings
- Both teaching strategies significantly improved student performance.
- Brain-based learning resulted in significantly higher gain scores and post-test performance.
- ANCOVA confirmed the difference was not due to initial ability.
- The effect size indicates the practical significance of BBL is substantial.

4. Discussion
The findings of this study reveal compelling evidence in support of the effectiveness of brain-based learning (BBL) strategies over traditional teaching methods in enhancing secondary-level students' academic performance. This interpretation aligns closely with contemporary educational research and the neurocognitive underpinnings of student learning and engagement.

4.1 Alignment with Existing Literature
The significantly higher post-test scores and gain scores in the experimental group exposed to BBL techniques support the growing body of research advocating for pedagogical strategies rooted in neuroscience. Studies by Caine & Caine (2020) [13] and Tokuhama-Espinosa (2019) [20] have emphasized the importance of integrating principles such as pattern recognition, emotion, and contextual learning into instructional models—key features of BBL. Our results mirror these conclusions by demonstrating enhanced cognitive engagement and knowledge retention among learners who experienced BBL.
Further, the findings corroborate the results from Bada (2022) [12], who found that secondary students taught physics using brain-compatible strategies outperformed their counterparts taught with conventional methods. Similarly, Okatahi, Apeh, and Iyiegbuniwe (2020) [16] reported that BBL significantly enhanced students' performance and classroom participation across core subjects in Nigerian secondary schools.
The observed effectiveness may also be understood in terms of Jensen's Brain-Based Learning Theory (2020) [6], which advocates for the activation of multiple brain regions through strategies like experiential learning, movement, real-life simulations, and emotional anchoring. These techniques were employed in the experimental group of this study and may explain the large effect size (Cohen's d=1.32) obtained, indicating both statistical and practical significance.

4.2 Theoretical Implications
From a theoretical standpoint, the results validate the constructivist and neurocognitive learning paradigms. Constructivist theory posits that learners actively construct knowledge through experience and reflection (Piaget, 1977; Vygotsky, 1978) [18, 21]. BBL provides a dynamic context in which such construction is facilitated by aligning teaching strategies with how the brain naturally learns.
Moreover, the findings are consistent with the Triadic

Model of Brain-Based Learning (Caine *et al*., 2020) [13], which integrates the cognitive (thinking), affective (feeling), and physiological (body/brain) domains. The enhanced performance among students in the BBL group suggests that activating these domains concurrently supports deeper learning, better recall, and more meaningful academic engagement.

4.3 Cognitive and Emotional Engagement

The study also highlighted differences in behavioral and emotional engagement between groups. Observational and feedback data revealed that students exposed to BBL were more enthusiastic, focused, and interactive during class sessions. This supports research by Adel & Saad (2019) [11], who found that BBL strategies significantly improved learners' motivation and working memory capacity. The positive emotional climate, novelty of activities, and personalization embedded in BBL lessons likely contributed to a more stimulating and rewarding learning experience.

In contrast, the control group's traditional instructional strategies—primarily teacher-centered lectures and rote memorization—lacked the interactive and multi-sensory features necessary to fully engage students. This supports the criticisms raised by Paul (2017) [17], who argued that traditional education systems often fail to accommodate the diverse learning styles and neurological differences among students.

4.4 Contribution to the Field

This study contributes to the growing empirical base advocating for instructional reform in secondary education. By demonstrating the superiority of BBL strategies in promoting academic success, the research provides policymakers, curriculum developers, and educators with evidence to consider neuro-educational approaches in mainstream schooling.

Furthermore, the findings emphasize the need for pre-service and in-service teacher training programs to incorporate neuroscience-informed pedagogy, as highlighted by Kosar & Bedir (2018) [15] and Rukminingsih *et al*. (2021) [5], who called for a shift from passive delivery models to active, brain-compatible teaching frameworks.

5. Conclusion

The present study conducted a systematic comparison between traditional teaching strategies and brain-based learning (BBL) approaches to evaluate their effectiveness in enhancing academic performance among secondary-level students. The empirical evidence obtained through quasi-experimental methods, statistical analyses, and qualitative feedback consistently pointed to the superiority of BBL strategies over conventional pedagogies.

Summary of the Comparative Effectiveness

The experimental group exposed to brain-based instruction significantly outperformed the control group receiving traditional instruction in terms of academic achievement, as measured by pre- and post-test evaluations. Descriptive and inferential statistics—including t-tests and ANCOVA—revealed substantial gains in cognitive outcomes, complemented by greater levels of emotional and behavioral engagement. The effect size calculated (Cohen's d) confirmed that these differences were not only statistically significant but also educationally meaningful.

These results are consistent with the findings of recent scholars such as Bada (2022) [12], Adel & Saad (2019) [11], and Jensen (2020) [14], who emphasize that learning environments designed to align with brain function—through multi-sensory stimulation, emotional engagement, contextual learning, and student-centered interaction—produce more sustainable academic outcomes. In contrast, traditional methods rooted in rote memorization and didactic instruction were found to be limited in engaging students' higher-order thinking or accommodating diverse learning styles.

Final Remarks on Enhancing Learning Environments through Innovative Pedagogy

The findings of this research underscore the urgent need to reimagine and reform traditional classroom environments. In the context of 21st-century education, where knowledge acquisition is increasingly complex, teaching strategies must transcend outdated paradigms and embrace innovative, scientifically grounded approaches. Brain-based learning not only improves academic achievement but also promotes critical thinking, creativity, motivation, and self-regulation among students—skills that are vital for success in the modern world.mIt is therefore recommended that educational institutions, curriculum developers, and teacher training programs integrate principles of brain-based instruction into their frameworks. Doing so will foster learning environments that are adaptive, inclusive, and neurologically compatible with how students learn best.

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