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IMPACT OF BRAIN-BASED TEACHING ON THE CONCEPTUAL UNDERSTANDING OF NEWTON'S LAWS OF MOTION

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ABSTRACT

Grounded in cognitive neuroscience, Brain-Based Teaching (BBT) enhances science instruction by aligning classroom practices with how the brain optimally learns and processes information. This mixed-methods study investigated the effectiveness of BBT in improving Grade 8 students' conceptual understanding of Newton's Laws of Motion. Conducted in a public school in Manila, Philippines, the study involved 51 students who participated in an intervention utilizing BBT strategies, including relaxed alertness, orchestrated immersion, and active processing. Quantitative data were collected through a validated 25-item concept test, daily performance worksheets, and a Student Perception of Instruction Questionnaire (SPIQ). Qualitative data came from student journals and semi-structured interviews. Findings showed a significant improvement in post-test scores (M = 9.35), as confirmed by a paired-sample t-test ($t(50) = 3.80$, $p < .001$) and a moderate effect size (Cohen's $d = 0.67$). Daily worksheets consistently received "Very Good" to "Excellent" ratings. One-way ANOVA results revealed significant differences in post-test scores across prior ability levels ($F(2, 48) = 10.07$, $p < .001$, $\eta^2 = .30$), suggesting that BBT's effectiveness varied depending on students' initial competence. The SPIQ survey revealed positive perceptions, with the highest mean score (3.6) indicating student satisfaction with the classroom environment and instructional support. Thematic analysis identified three key themes: enhanced instruction through various classroom activities, insightful learning, and retention of learning. Overall, BBT was found to be effective in fostering conceptual understanding and promoting a positive learning environment. Its novelty lies in highlighting the differentiated impact of BBT based on prior achievement in a resource-constrained public school context.

Keywords: brain-based teaching; relaxed alertness; orchestrated immersion; active processing; Newton's Laws of motion

INTRODUCTION

Physics is a foundational science critical to technological advancement and societal progress, with applications ranging from medical diagnostics to renewable energy solutions. Despite its importance, students often find physics abstract and conceptually challenging, resulting in disengagement and poor performance, especially at the secondary level (Wangchuk et al., 2023; My et al., 2025). This issue is especially pressing in the Philippines, as evidenced by the 2019 Trends in International Mathematics and Science Study (TIMSS), where Filipino students scored an average of 249 in science—substantially below the international benchmark of 489 and far behind high-performing countries like Singapore (TIMSS & PIRLS International Study Center, 2020; Teacher Magazine Southeast Asia, 2019). The 2022 Programme for International Student Assessment (PISA) further highlighted this gap, placing the Philippines near the bottom in science, reading, mathematics, and creative thinking domains (OECD, 2023). These foundational

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challenges in science education highlight an urgent need for pedagogical strategies that foster deep conceptual understanding early in students' academic trajectories.

In response to these persistent issues in conceptual learning, this study investigates the effectiveness of Brain-Based Teaching (BBT) in improving Grade 8 students' understanding of Newton's Laws of Motion within a public school setting in Manila, Philippines. Conceptual difficulties in physics, particularly in the areas of force and motion, have long been documented across various educational systems (McDermott & Redish, 1999; Duit & Treagust, 2003; Aflalo & Raviv, 2020; Wang & Gao, 2025), often stemming from deep-seated misconceptions and limited engagement with student-centered teaching strategies. In the Philippine context, gaps in the implementation of the science curriculum have been noted, especially in translating curriculum standards into effective teaching practices due to inadequate teacher preparation, resource constraints, and large class sizes (Usma-Kaibat et al., 2025). These challenges underscore the need for instructional approaches that are not only pedagogically robust but also grounded in how students naturally process and retain information. BBT, therefore, provides a promising pedagogical framework by aligning teaching strategies with cognitive and neuroscientific principles (Tokuhama-Espinosa, 2021; Jensen, 2008), particularly in promoting conceptual change in complex topics like Newtonian mechanics. This study responds to that need by situating its intervention at the intersection of cognitive science and classroom practice, offering an evidence-based approach to reframe how science is taught and learned.

Brain-Based Teaching (BBT) is a pedagogical approach grounded in cognitive neuroscience, emphasizing strategies that align with the brain's natural learning processes. It recognizes that learning is influenced not only by content delivery but also by learners' emotional states, prior experiences, and social interactions (Tokuhama-Espinosa, 2011; Sari et al., 2025). BBT incorporates key principles such as relaxed alertness (a low-threat, high-challenge environment), orchestrated immersion (learning that is context-rich and emotionally engaging), and active processing (reflection and elaboration that solidify understanding) as originally articulated by Caine and Caine (1990, 1997). These principles are designed to optimize memory formation, metacognition, and conceptual transfer by leveraging the brain's innate capacity for pattern recognition and meaning-making (Willis, 2007; Jensen, 2008). In science education, BBT has been operationalized through strategies such as storytelling, peer teaching, visual mapping, movement, and emotion-integrated inquiry tasks—each aimed at reducing cognitive overload and enhancing neural engagement (Sousa, 2017; Tokuhama-Espinosa, 2020). These techniques have been shown to activate multiple brain regions simultaneously, thereby supporting long-term retention and increased student motivation (Immordino-Yang & Damasio, 2007; Boon, 2024). Moreover, BBT supports inclusive and differentiated instruction by addressing the neurodiversity of learners, allowing for multiple points of entry into complex content (Howard-Jones, 2014; Pradeep et al., 2024). By aligning pedagogy with how the brain functions optimally, BBT provides a robust framework for designing emotionally safe, cognitively stimulating, and socially responsive classrooms.

Existing studies have consistently demonstrated that Brain-Based Teaching enhances academic performance across multiple disciplines, including mathematics, biology, and physics. In Saleh's (2011) study, students exposed to brain-compatible teaching strategies showed significantly higher conceptual gains in Newtonian mechanics compared to those taught using traditional methods. Saleh and Subramaniam (2018) further confirmed these findings in a Malaysian context, emphasizing that the incorporation of BBT principles—particularly active processing and emotional engagement—led to deeper understanding and better long-term retention. Bada and Jita (2022) highlighted in a study on heat energy that students who received BBT-based instruction not only outperformed their peers academically but also exhibited higher motivation and participation. Similarly, Pradeep et al. (2024) documented how BBT facilitated improved performance in middle school science classes by reducing cognitive overload and fostering metacognitive awareness. Local research also affirms these trends: Escultura and Ricafort (2019), Bantillo (2024), and Torio and Cabrillas-Torio (2016) reported that brain-compatible instructional strategies significantly enhanced student motivation and interest in science subjects. Collectively, these findings affirm the potential of BBT to improve science learning outcomes by creating emotionally safe, cognitively rich, and physically engaging classroom environments. However, despite this growing body of evidence, most of these studies have been conducted in private institutions or high-performing schools, and few have focused specifically on Newtonian mechanics or examined BBT's effectiveness within public school systems in the Philippines—highlighting the need for contextualized research, such as the present study.

Aligned with Sustainable Development Goal 4 (Quality Education), which advocates for inclusive, equitable, and effective learning opportunities for all, this study contributes to the enhancement of science education through research-based pedagogical innovations. While the Philippines' K–12 science curriculum was designed to strengthen conceptual understanding beginning in Grade 3, significant challenges persist in classroom implementation. Observations in the target public school revealed widespread misconceptions among Grade 8 learners about Newton's Laws of Motion, particularly difficulties in distinguishing among the laws of inertia, acceleration, and interaction forces. In a pilot study conducted prior to the primary intervention, preliminary classroom data revealed that fewer than 30% of the students could correctly articulate the concept of net force during formative assessments. Diagnostic tools, including short quizzes, reflective writing prompts, and think-pair-share discussions, were used during the initial lessons. Analysis of student responses uncovered persistent misconceptions; for instance, many believed that a constant force is necessary to maintain motion or were unable to differentiate between balanced and unbalanced forces. These findings are consistent with recent literature in physics education, which also highlights the challenges students face in understanding Newton's Laws and the need for instructional strategies that promote conceptual change, confirming that even with curriculum-aligned instruction, traditional lecture-based approaches are often insufficient in promoting lasting conceptual understanding (Ding et al., 2024; Suhandi et al., 2025; Sinuraya et al., 2025).

Despite growing international interest in BBT, a significant gap remains concerning its application to Newtonian mechanics at the Grade 8 level, particularly in under-resourced Philippine public schools. Few studies have used a mixed-methods approach to evaluate both the cognitive and affective outcomes of BBT in real-world classroom settings. Grade 8 is a particularly critical stage in the Philippine K–12 science curriculum, as it marks students' first formal exposure to classical mechanics. At this stage, learners transition into what Piaget termed the formal operational phase—characterized by the emergence of abstract and hypothetical reasoning, which is essential for comprehending concepts such as force and motion (Inhelder & Piaget, 1958). However, as shown in studies, many students continue to struggle with Newtonian concepts, reinforcing the inadequacy of conventional methods (Kaniawati et al., 2019; Çelikkanlı & Kızılcık, 2022).

Moreover, there is limited research exploring the implementation of BBT in Philippine public school settings, where contextual constraints such as overcrowded classrooms, limited resources, and high student-to-teacher ratios may hinder effective instruction (Gumarang & Gumarang, 2021). This study addresses these gaps by applying BBT in a public secondary school and assessing its impact on conceptual understanding and student engagement using a mixed-methods approach.

Thus, the primary objective of this study is to determine the effectiveness of Brain-Based Teaching in improving students' conceptual understanding of Newton's Laws of Motion and to explore how this approach shapes their learning experiences. Specifically, it evaluates (1) the extent to which BBT improves comprehension of Newtonian mechanics, (2) how students perceive their BBT-based learning experiences, and (3) how outcomes vary based on students' prior academic performance. This multifaceted approach enables a nuanced understanding of BBT's impact on learners with varying levels of readiness.

Taken together, this study builds on established research supporting Brain-Based Teaching's (BBT) effectiveness, notably addressing its under-explored application to Newtonian physics in Philippine secondary education. Given the persistently low science assessment performance and widespread misconceptions, this study is both timely and necessary, aiming to assess the conceptual impact of BBT and learner experience in a real classroom context using a mixed-methods approach. Its novelty lies in its specific focus on Newtonian mechanics at the Grade 8 level, its use of a mixed-methods framework to capture both cognitive and affective outcomes, its contextual grounding in a Philippine public school environment where BBT has not been extensively studied, and its examination of how variations in prior academic performance influence post-test outcomes, offering a more nuanced perspective on how BBT impacts learners with different levels of initial understanding. By situating the research in an authentic, resource-constrained educational setting, this study contributes original insights into the effectiveness of neuroscience-informed teaching strategies in enhancing conceptual understanding and promoting reflective, student-centered learning. Ultimately, it affirms the relevance of Brain-Based Teaching for inclusive, equitable, and sustainable science education, aligning with Sustainable Development Goal 4.

METHODS

This study employed a convergent mixed-methods design to evaluate the impact of Brain-Based Teaching (BBT) strategies on the conceptual understanding of Grade 8 students of Newtonian mechanics, specifically Newton's Three Laws of Motion: the Law of Inertia, the Law of Acceleration, and the Law of Interaction. The research was conducted during the first grading period and aligned with the K–12 Science curriculum for Grade 8 in a public secondary school in Manila, Philippines. The design and sequencing of the research stages were adapted from the instructional intervention models of Fraenkel et al. (2019), Joyce et al. (2015), and Creswell and Plano Clark (2018), and were modified to reflect the local educational context and curricular requirements.

The study was implemented in five stages, as shown in Figure 1, each addressing key phases of the intervention and data collection process. Stage 1 involved preparing the research instruments and obtaining ethical clearance. Stage 2 focused on the development and validation of BBT-aligned lesson plans. Stage 3 entailed the classroom implementation of the BBT intervention. Stage 4 covered the collection of both quantitative and qualitative data. Finally, Stage 5 was dedicated to the statistical and thematic analysis of the results. This structured approach ensured coherence across phases and alignment with both curricular goals and research rigor (Creswell & Plano Clark, 2018; McMillan, 2022).

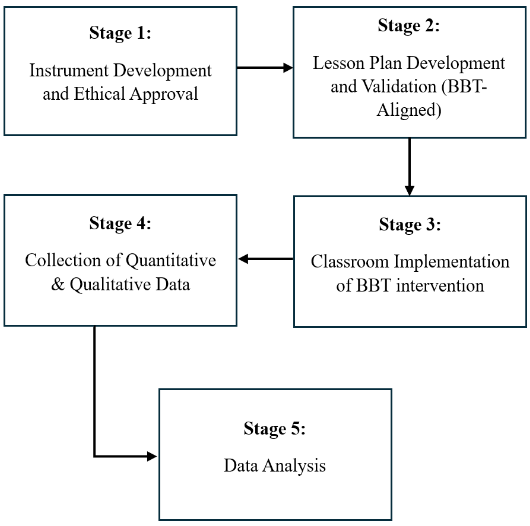

Figure 1. Research Stages

Stage 1 (Preparatory Phase) involved the development and pilot testing of research instruments, securing of ethical clearance from relevant school authorities, and the orientation of the participating teacher and students. During this phase, participants were informed of the research objectives and procedures, and coordination with the classroom teacher was conducted to ensure the intervention was integrated seamlessly into the class schedule.

Stage 2 (Development and Validation of BBT-Aligned Lesson Plans) focused on designing instructional materials grounded in Caine and Caine's (1994) 12 principles of Brain-Based Teaching, as well as the three core components of effective instruction: Relaxed Alertness, Orchestrated Immersion, and Active Processing. To ensure academic rigor and developmental suitability for Grade 8 learners, the lesson plans were reviewed and validated by three experts in physics education, confirming alignment with curriculum standards and content accuracy. Upon finalization of the instructional materials, a pre-test was administered to all participants to establish a baseline conceptual understanding before implementing the BBT intervention.

Stage 3 (Implementation Phase) spanned two weeks within regular classroom instruction. The BBT-aligned lessons employed brain-based strategies that support emotional safety through supportive learning climates and deliberate reflective pauses that help stabilize emotions and prime the brain for learning. They also integrated multisensory engagement, including gestures, movement, storytelling, and visual–auditory input, which research shows activates multiple neural pathways and enhances memory encoding and retention. Lessons were deliberately structured to foster reflective thinking and collaborative learning, both of which leverage embodied cognition and peer interaction to strengthen neural integration. The intervention was delivered by the classroom teacher, who also served as the researcher, ensuring instructional authenticity. Meanwhile, an independent observer used a structured fidelity checklist, grounded in implementation science, to systematically monitor adherence, dosage, and contextual factors, ensuring the intervention remained consistent and any deviations were duly recorded (Bergmann et al., 2023).

Stage 4 (Data Collection Phase) involved gathering both quantitative and qualitative data. Quantitative data included pre-test and post-test scores on a diagnostic test of conceptual understanding, as well as daily worksheet submissions. Qualitative data were obtained through student journal entries and semi-structured interviews. Additionally, students completed the Student

Perception of Instruction Questionnaire (SPIQ) to assess their cognitive, emotional, and behavioral engagement with the BBT intervention.

The study involved 51 Grade 8 students, selected through purposive sampling from the target public school. Participants were identified based on the recommendations of their science teachers, their availability during the intervention period, and their willingness to participate—criteria consistent with purposive sampling strategies in educational research (Palinkas et al., 2015; Etikan et al., 2015; Khumraksa & Burachat, 2022). To measure conceptual understanding, the researchers developed a 25-item multiple-choice diagnostic test aligned with the curriculum. Three experts validated the instrument and pilot-tested it with 115 Grade 12 students enrolled in a physics course. This yielded a Kuder-Richardson Formula 20 (KR-20) reliability coefficient of 0.72, indicating acceptable internal consistency for educational assessments (Urbina, 2014; Ntumi et al., 2023). Using older students for the pilot ensured effective item discrimination while minimizing floor effects when administered to Grade 8 students (Teresi et al., 2022).

Stage 5 (Data Analysis Phase) consisted of the statistical and thematic analysis of the collected data. The quantitative data were collected through pre- and post-tests, as well as daily worksheet submissions. The conceptual understanding test was administered before and after the intervention to assess learning gains. Daily worksheets were evaluated using Griffin's (1999) performance level conversion scheme to ensure consistent scoring across sessions. Quantitative analysis was conducted using IBM SPSS 16.0. Paired samples t-tests were employed to examine pre-post score differences, and Cohen's d was used to determine effect size and practical significance.

To explore whether prior academic performance moderated learning outcomes, a one-way ANOVA was conducted on post-test scores. Students were categorized into low, medium, and high achievers based on their pre-test scores using the mean ± 0.5 standard deviation method, as shown in Table 1. Students scoring below −0.5 SD were classified as low achievers; those within ±0.5 SD, as medium; and those above +0.5 SD, as high achievers. This stratification method allowed for meaningful group comparisons (Cohen, 1988). Tukey's HSD post hoc test was applied to determine statistically significant differences among the three achievement levels.

Table 1. Achievement Group Stratification Based on Pre-test Scores

Achievement Group	Pre-test Score Range	Description
Low Achievers	Below −0.5 SD	Students with pre-test scores significantly below the average
Medium Achievers	Within ±0.5 SD	Students with pre-test scores near the average
High Achievers	Above +0.5 SD	Students with pre-test scores significantly above the average

For the qualitative data, student journals and interview transcripts were analyzed using Braun and Clarke's (2006) six-phase thematic analysis: familiarization with the data, generation of initial codes, identification of themes, review of themes, definition and naming of themes, and production of the final report. NVivo 12 software supported the coding and organization of qualitative data. Journal entries, which followed structured prompts adapted from Caine and Caine (1994) — (1) What did I do? (2) Why did I do it? and (3) What did I learn? — provided insight into students' metacognitive and affective responses. Semi-structured interviews were conducted with a representative sample of 12 students, stratified by achievement level. To ensure credibility and trustworthiness, member checking was conducted to validate participant responses, and peer validation was employed to confirm consistency in coding and thematic interpretation.

To analyze students' perceptions of the Brain-Based Teaching (BBT) intervention, descriptive statistics, specifically mean and standard deviation, were employed for the Student Perception of Instruction Questionnaire (SPIQ), an 11-item Likert-type instrument adapted from Varthis (2016). The survey consisted of 11 parallel statements that captured three key dimensions: cognitive challenge, emotional engagement, and behavioral participation. Each item was rated on a 4-point Likert continuum ranging from Strongly Agree (4) to Strongly Disagree (1). Interpretation of the mean scores followed this criterion: 3.25 - 4.00 = Strongly Agree, 2.50 - 3.24 = Agree, 1.75 - 2.49 = Disagree, and 1.00 - 1.74 = Strongly Disagree, as shown in Table 2. This quantitative analysis served to identify trends in students' perceptions of the BBT strategies and to support data triangulation with qualitative responses obtained through student journals and interviews.

Table 2. Interpretation Scale for SPIQ Mean Scores

Mean Score Range	Interpretation
3.25 – 4.00	Strongly Agree
2.50 – 3.24	Agree
1.75 – 2.49	Disagree
1.00 – 1.74	Strongly Disagree

This comprehensive analytical approach reflects the logic of a convergent parallel mixed-methods design (Creswell & Plano Clark, 2018), in which quantitative and qualitative data were collected and analyzed concurrently, then integrated during interpretation. This design enabled the researchers to assess both measurable learning outcomes and the lived learning experiences of students, providing a holistic evaluation of Brain-Based Teaching's effectiveness in improving conceptual understanding and fostering student-centered learning in science education.

RESULTS AND DISCUSSION

This study investigated the effectiveness of Brain-Based Teaching (BBT) in enhancing the conceptual understanding of Grade 8 students of Newton's Laws of Motion. The intervention integrated BBT principles such as emotional safety, multisensory engagement, and active processing to foster deeper learning. As shown in Table 3, the results from the 25-item concept-based pre-test and post-test revealed a notable improvement in student performance, with the mean score rising from 7.63 in the pre-test to 9.35 in the post-test.

Table 3. Paired Samples Statistics of Pre-test and Post-test Scores

	N	Mean	SD
Pre-test	51	7.63	2.21
Post-test	51	9.35	2.95

This gain suggests that the implementation of BBT strategies positively influenced students' comprehension of fundamental physics concepts, supporting the view that aligning instructional practices with cognitive and neuropsychological principles can lead to measurable academic benefits.

Moreover, as shown in Table 4, a paired-sample t-test confirmed that this improvement was statistically significant, $t(50) = 3.799$, $p < .001$. The effect size, measured using Cohen's $d = 0.67$, indicates a moderate to high practical significance. These results suggest that BBT had a meaningful impact on students' understanding of Newtonian mechanics. However, the increased post-test standard deviation (2.95) compared to the pre-test (2.45) suggests greater variability in student outcomes following the intervention. This variability may be attributed to individual differences in cognitive processing, prior knowledge, or levels of engagement with the BBT approach—a trend also noted in Bada and Jita's (2023) study on heat energy, where learner differences moderated learning gains under BBT.

Table 4. Paired t-test and Cohen's d Results between Pre-test and Post-test Scores

Paired Differences	Mean	SD	Std. Error Mean	t	df	p-value	Cohen's d
Pre-test – Post-test	-1.725	3.244	0.454	-3.799	50	0.000*	0.67

In addition to the pre-test and post-test scores, the students' daily worksheets also provided valuable quantitative data for the study. To ensure consistency, the students' performance data were converted using the conversion schemes and descriptions provided by Griffin (1999). Table 5 presents the students' performance across six sessions. The data indicates that the majority of students achieved a "Very Good" to "Excellent" rating in their worksheets. Notably, sessions 3, 4, and 5 emerged as the most successful, as no student in these sessions scored "Fair" or "Poor." The worksheets revealed a clear trend of improvement, with students performing at higher levels as the lessons progressed. In particular, session 3 saw the highest proportion of "Excellent" ratings, further reinforcing the positive impact of the teaching approach on student performance.

Table 5. Performance in Daily Worksheets

Session	Excellent (%)	Very Good (%)	Good (%)	Fair (%)	Poor (%)
1	66.67	12.50	81.25	6.25	-
2	91.49	6.38	38.30	55.32	-
3	66.67	29.41	4.26	3.92	-
4	62.50	4.26	4.17	2.08	-
5	66.67	29.17	4.17	-	-

These outcomes are consistent with previous studies that emphasize the pedagogical value of brain-compatible instruction in science education. For example, Sani et al. (2019) found that Grade 8 students taught electric circuits using BBT achieved higher conceptual mastery than those under traditional instruction, as shown by a higher N-gain score. Likewise, Bada and Jita (2023) demonstrated that BBT significantly improved retention in heat-energy concepts among Nigerian students, particularly in diverse learning contexts. Nwankwo (2021) also noted BBT's effectiveness in fostering understanding of projectile motion, further supporting the strategy's adaptability across physics topics. These studies collectively highlight the effectiveness of BBT in fostering sustained conceptual development, reducing achievement gaps, and engaging learners more effectively than conventional methods. Given the cognitive underpinnings of BBT, these findings advocate for its broader integration in science instruction to foster deeper learning and improve equity in educational outcomes.

To explore whether prior ability influenced post-test performance, a one-way ANOVA was conducted using pre-test scores categorized into Low, Medium, and High groups based on the mean ± 0.5 standard deviation method. This approach ensured a data-driven and balanced classification of learners based on their initial conceptual understanding. As shown in Table 6, the results revealed a statistically significant difference among the three groups, $F(2, 48) = 10.07$, $p < .001$, with a partial eta squared (η^2) of .30, indicating a large effect size. This finding suggests that prior knowledge has a significant impact on the learning gains achieved through Brain-Based Teaching (BBT). Specifically, students who entered the intervention with higher pre-test scores demonstrated superior post-test performance compared to their peers in the medium and low groups.

Table 6. One-Way ANOVA Summary Table for Post-test Scores by Prior Ability Group

Source	df	MS	F	p	η^2
Between Groups	2	82.24	10.07	< .001	.30
Within Groups	48	8.17			
Total	50				

Further analysis using Tukey HSD post hoc tests, as shown in Table 7, revealed that the High prior ability group ($M = 12.32$, $SD = 2.63$) performed significantly better than both the Medium ($M = 9.29$, $SD = 3.20$, $p = .011$) and Low ($M = 7.82$, $SD = 2.52$, $p < .001$) groups. Although the Medium vs. Low comparison was not statistically significant ($p = .068$), the data suggest a progressive pattern of performance relative to initial ability. These findings highlight the differential responsiveness to BBT, wherein students with higher pre-existing conceptual understanding benefited most from the intervention.Importantly, the observed gains among Low and Medium achievers, although more modest, underscore BBT's potential to support students across the achievement spectrum. This suggests that while BBT is particularly effective in deepening existing knowledge, it also provides meaningful opportunities for conceptual growth among less prepared students through its emphasis on active processing, multimodal engagement, and contextualized learning. These insights contribute to a more nuanced understanding of BBT's utility in mixed-ability classrooms, emphasizing the need for further instructional refinement to maximize its impact for all learners.

Table 7. Tukey HSD Post Hoc Comparisons for Post-test Scores by Prior Ability Group

Comparison	Mean Difference	SE	95% CI (Lower, Upper)	p	Significant
High vs. Low	4.50	1.01	2.00, 7.00	< .001	Yes
High vs. Medium	3.03	0.96	0.67, 5.39	.011	Yes
Medium vs. Low	1.47	0.91	-0.84, 3.78	.068	No

This study offers a novel contribution to the literature by highlighting the differentiated effects of Brain-Based Teaching (BBT) across varying levels of student achievement, a dimension that has received limited attention in previous research. While earlier studies (e.g., Sani et al., 2020; Bada & Jita, 2023) have established the overall effectiveness of BBT in improving student learning outcomes in science, they have generally treated learners as a uniform group, without examining how differences in prior knowledge may shape the impact of such interventions. The present findings address this gap by demonstrating that students with higher initial conceptual understanding derived greater benefit from the BBT approach. This suggests that while BBT is a powerful pedagogical tool, it may inadvertently amplify existing academic disparities if not implemented with strategies to support lower-achieving learners. Consequently, the study raises important considerations for equity in science instruction, emphasizing the need for differentiated scaffolding within brain-based models to ensure that all students—regardless of starting point—can fully engage with and benefit from enriched learning experiences.To assess students' perceptions of Brain-Based Teaching (BBT) following the intervention, a Student Perception of Instructional Quality (SPIQ) survey was administered to 51 Grade 8 participants. This tool measured students' views regarding the learning environment, classroom activities, teacher facilitation, and their level of engagement. As shown in Table 8, the survey results reveal overwhelmingly positive responses, indicating that most students experienced meaningful cognitive and emotional benefits following the BBT intervention.

Table 8. Student Perceptions of Brain-Based Teaching

Statement	Weighted Mean	Interpretation
The teacher created a successful learning environment.	3.6	Strongly Agree
The teacher effectively presented the necessary tools and techniques.	3.6	Strongly Agree
The Brain-Based Teaching Approach helped develop my abilities and skills in the subject.	3.4	Strongly Agree
The Brain-Based Teaching Approach was appropriate for the stated level of the class.	3.3	Strongly Agree
The Brain-Based Teaching Approach was effectively organized.	3.5	Strongly Agree
The overall rate of this Brain-Based Teaching Approach was excellent.	3.5	Strongly Agree
I found the learning experience to be enjoyable.	3.5	Strongly Agree
I am satisfied with my effort in this Brain-Based Teaching Approach.	3.6	Strongly Agree
The Brain-Based Teaching Approach promotes a conducive learning environment.	3.4	Strongly Agree
I learned a lot through the Brain-Based Teaching Approach.	3.5	Strongly Agree
I remember much of what I learned through the Brain-Based Teaching Approach.	3.5	Strongly Agree

Note: 1.00 - 1.74 = Strongly Disagree; 1.75 - 2.49 = Disagree; 2.50 - 3.24 = Agree; 3.25 - 4.00 = Strongly Agree

Three items received the highest mean rating (3.6 out of 4), indicating that students strongly agreed their classroom was supportive, instructional tools were effectively presented, and their efforts during BBT were personally satisfying. These outcomes align closely with recent studies demonstrating improved student perceptions under brain-based instruction. For instance, Islam et al. (2023) reported that BBT significantly increased intrinsic motivation among Grade 8 learners in mathematics, while Funa et al. (2024) found in a meta-analysis that brain-based strategies (e.g., relaxed alertness, active processing, spaced learning) led to substantive gains in conceptual understanding across STEM subjects. Furthermore, a study by Alkhassawneh and Al Sharif (2025) showed that integrating educational neuroscience principles—such as cognitive load management and scaffolding—into classroom activities significantly enhanced middle school students' perceived learning effectiveness in science and technology classes. This alignment with current literature supports the conclusion that SPIQ feedback reflects both cognitive alignment and emotional resonance—hallmarks of effective brain-compatible pedagogy in the classroom.Using student perception surveys as a complement to quantitative performance data has gained credibility in recent educational research (Shabaan & Mohammed, 2022), offering insight into how pedagogy impacts learners' cognitive and affective experiences. In this study, the positive student feedback not only corroborates the improved cognitive outcomes observed in the post-test scores but also underscores the value of Brain-Based Teaching in creating emotionally supportive, intellectually stimulating, and engaging learning environments—key factors in fostering lasting educational change.

Thematic analysis, following Braun and Clarke's (2006) phases, revealed three recurrent themes in the students' daily journal logs and the semi-structured interviews: *Enhanced Instruction through Various Classroom Activities*, *Insightful Learning*, and *Retention of Learning*. These qualitative insights support the quantitative data obtained from the pre- and post-tests, further emphasizing the positive impact of Brain-Based Teaching (BBT).

Enhanced Instruction through Various Classroom Activities. One of the most prominent themes observed in the journal logs was the effectiveness of various classroom activities in enhancing student learning. Students consistently mentioned activities such as group discussions, experiments, peer tutoring, problem-solving tasks, and the use of multimedia (e.g., videos and interactive lessons) as significant contributors to their learning experience. These activities appeared to engage students and provide them with diverse opportunities to understand complex concepts.

For example, one student wrote, "We did a group activity with my classmates, and we were able to apply what we learned to solve problems together." – Student 1. This comment reflects how group work and collaboration fostered a deeper understanding of the material. Another student noted, "We watched a video clip showing the third law of motion," – Student 6, indicating that multimedia tools were also an integral part of their learning process, enhancing engagement and facilitating visual learning.

These accounts support Zengin and Balım (2020), who concluded that active learning environments—especially those incorporating group-based and experiential strategies—enhance conceptual understanding in science. BBT's alignment with multimodal instruction effectively caters to diverse learning preferences, thereby increasing engagement and supporting differentiated instruction (Jensen, 2020).

Insightful Learning. Another key theme that emerged from the journal entries was the students' reflective thinking and deeper insights into the content they were learning. Many students articulated that they were not merely focused on achieving good grades but rather on the knowledge and experiences they gained through the activities. This theme highlights the significance of meaningful learning in BBT, where students interact with content in ways that promote lasting comprehension.

One student reflected, "I did the activities because I know that I want to learn something. I also feel excited and happy whenever we are doing activities in our class." – Student 10. Another student shared, "I answered each question in the worksheet because I know it will give me more knowledge about the topic." – Student 34. These comments indicate that the students perceived the activities as opportunities for genuine learning, rather than merely tasks to complete for a grade. Their engagement and positive attitudes towards the learning process align with Aydin and Yel (2011), who demonstrated that BBT encourages deeper reflection and self-motivated learning, leading to a more meaningful connection with the content.

The insights gained from these reflective responses also correspond with the improved post-test scores, reinforcing that the activities provided not only content knowledge but also sparked a sense of curiosity and enthusiasm for learning. The reflective nature of Active Processing in BBT encourages students to connect their learning to real-life experiences, making the content more relevant and enjoyable.

Retention of Learning. The third recurring theme in the journal logs was the retention of learned material. The students frequently reflected on how they were able to retain and recall the concepts they learned during the lessons. For example, one student noted, "I learned that when a low force or constant force hits a heavy mass of an object, it will move slower than the lighter mass because when the mass is heavier, we need to double the force."- Student 13. Another student explained the formulas related to Newton's Laws, saying, "I learned how to calculate the missing components of the Law of Motion. F stands for Force; the unit of force is N or Newtons. A stands for Acceleration, the unit of Acceleration is m/s^2 or meters per second squared." – Student 25.

These reflections indicate that the students were able to retain and recall core concepts learned during the lessons, which is a key goal of Active Processing in Brain-Based Teaching. The journal logs showed that students were not only able to articulate what they learned but could also apply these concepts to different contexts. This aligns with Saleh and Subramaniam (2018) and Veresová and Záhorec (2020), who found that BBT fosters better retention by encouraging students to reflect on the material, actively engage with it, and make meaningful connections.

Additionally, the improvement in students' post-test scores, as shown by the paired samples t-test, supports the idea that BBT not only enhances immediate learning but also contributes to the long-term retention of knowledge. By reinforcing learning through activities that promote critical thinking and reflection, BBT helps ensure that students retain and apply what they have learned.

It is also noteworthy that these themes align with the results from the students' perception questionnaire, where three statements received the highest mean scores, indicating strong agreement from the students. Two of these statements directly correspond to the themes identified in the journal logs: "The teacher effectively presented tools such as materials, skills, and techniques needed" (Student 12), which corresponds to the various classroom activities consistently mentioned in the journal logs. "I am satisfied with my effort in this Brain-Based Teaching Approach" – Student 40, is supported by the insightful learning reflected in the students' responses, illustrating their engagement and satisfaction with the learning process.

This triangulation reinforces the view that BBT not only enhances conceptual development but also significantly bolsters student satisfaction, agency, and long-term retention. The convergence of evidence across student journals, perception surveys, and test results highlights the multidimensional benefits of BBT. Neuroscientific reviews emphasize that active learning environments—characterized by emotional safety, novelty, and social interaction—facilitate better memory consolidation and deeper engagement (Dubinsky & Hamid, 2024). Additionally, meta-analytic findings indicate that brain-based strategies—such as active processing, relaxed alertness, and spaced reinforcement—yield significant conceptual gains across STEM subjects (Funa et al., 2024). Finally, research in neuroscience confirms that learning strategies aligned with cognitive-load management and metacognitive support are associated with stronger comprehension and memory retention (Tasawar et al., 2024). Taken together, the convergence of qualitative and quantitative evidence in this study confirms the effectiveness of BBT as a neuroscience-aligned pedagogy, capable of supporting sustained conceptual mastery, intrinsic motivation, and learner autonomy.

Despite its contributions, this study has several limitations. First, it employed a quasi-experimental design without a control group, limiting the ability to draw causal inferences. Future research should consider randomized controlled trials or matched comparison groups to validate findings. Second, while stratification by prior ability revealed meaningful differences, other potential moderating factors, such as gender, learning styles, or socio-emotional readiness, were not analyzed. Studies employing multivariate models or mixed ANOVA could better capture the interaction of these variables. Third, this research was conducted in a single public school, which may limit the generalizability of the findings. Multi-site studies involving diverse educational settings would strengthen the applicability of BBT across contexts.

Furthermore, the novelty effect associated with a new instructional method may have influenced students' motivation and engagement, potentially inflating short-term gains. Future longitudinal studies are needed to examine whether the positive effects of BBT are sustained over time. As Creswell and Plano Clark (2018) emphasize, long-term follow-up in mixed-methods research is crucial for distinguishing between transient engagement and genuine conceptual change. Lastly, while the study documented BBT's success in promoting conceptual gains, its implementation may require significant teacher training and support, particularly in resource-constrained schools. Research exploring scalable models for teacher professional development in brain-based instruction would be a valuable next step.

CONCLUSION

This study has demonstrated that Brain-Based Teaching (BBT) significantly improves students' conceptual understanding of Newton's Laws of Motion, as evidenced by a statistically significant increase in post-test scores and positive learner perceptions. The quantitative results, supported by a moderate to high effect size, and the qualitative data from student reflections and classroom observations, suggest that BBT not only enhances academic performance but also fosters a more meaningful, engaging, and emotionally supportive learning environment. Furthermore, the differential effects observed among students with varying levels of prior ability highlight BBT's potential to tailor instruction in mixed-ability classrooms, contributing to more equitable learning outcomes. The practical implications of these findings are far-reaching: for teachers, the study offers an instructional framework grounded in neuroscience that encourages active learning and reflective thinking; for educational administrators, it affirms the value of cultivating learning environments that align with how the brain learns best, even within resource-limited public school settings. Applying these strategies in science education may lead to sustained improvements in both student achievement and motivation, ultimately supporting the broader goals of inclusive and quality education as emphasized in Sustainable Development Goal 4. Thus, BBT emerges not merely as an instructional alternative but as a pedagogical innovation with the capacity to transform how science is taught and experienced in the classroom.

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