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Brain-based learning practices among pre-service teachers in Southeast Asia: A mixed-methods study from a neuroeducational perspective

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ABSTRACT

The Brain-Based Learning (BBL) approach in language teaching is relatively new among pre-service teachers in Indonesia and the Philippines. This study examines students' perceptions of BBL-based teaching, identifies pre-service teachers' challenges and instructional performance, and evaluates the effectiveness of the BBL approach in Indonesian and Philippine educational contexts. Using a mixed-methods design with a one-group pre-test–post-test pre-experimental structure, the study involved 30 pre-service teachers undertaking their teaching practicum in six junior high schools and six senior high schools across Indonesia and the Philippines. A total of 322 students aged 13–17 years participated in the study and were selected through purposive sampling. Quantitative data were collected through student perception questionnaires, pre-tests, and post-tests, while qualitative data were gathered through semi-structured interviews. The primary data were analyzed using descriptive statistics, correlation analysis, and paired-sample tests, while secondary data were analyzed through thematic analysis to complement and explain the quantitative findings. The findings reveal that students generally hold positive perceptions of BBL-based instruction; however, these perceptions do not always translate into improved learning outcomes when BBL principles are not fully aligned with brain-compatible learning processes. The study also identifies key instructional gaps, particularly in promoting meaningful learning and incorporating reflective pauses. Despite these challenges, implementing BBL positively affects students' learning outcomes. Overall, the findings highlight the importance of ongoing neuroeducation-based teacher training to better align pedagogical practices with how the brain learns, supporting more meaningful and effective language learning experiences.

Keywords: Brain-based learning; neuroeducation; pre-service teachers

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INTRODUCTION

Language instruction in Indonesia and the Philippines should be directed toward becoming more meaningful, in-depth, and enjoyable. Meaningful learning connects language content to students' prior experiences and linguistic knowledge (Cooke et al., 2024); deep learning emphasizes comprehensive exploration of linguistic elements (Fuchs et al., 2024); and joyful learning involves a balanced engagement of mental and physical processes without emotional pressure (Gkintoni et al., 2025). These three dimensions align with the

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twelve core principles of Brain-Based Learning (BBL) as developed by Caine and Caine (1991). However, unlike in developed countries where neuroeducation theory has been implemented for decades, BBL remains relatively new in Indonesia and the Philippines. As a result, language teaching practices remain largely teacher-centered and do not align with brain-compatible approaches (Alshokhada et al., 2026). This is problematic, as language acquisition is fundamentally a transactional process embedded in real-life communicative needs (Shruthi et al., 2025). Moreover, many language teachers have limited awareness of how brain functions support cognitive processes involved in language learning, such as pattern recognition, sequencing, and meaning construction (Peck, 2024). Therefore, it is essential to observe and train pre-service teachers in implementing the BBL approach. This research is crucial because it offers a pathway to develop more effective instructional designs by leveraging the neurological mechanisms of learning, fostering language instruction that is more contextual, authentic, and aligned with how the brain naturally learns.

BBL is a comprehensive teaching approach grounded in the latest findings from neuroscience (Amjad et al., 2022; Rodgers & Hales, 2021). From a neuroeducational perspective, brain-based education emphasizes how the brain naturally learns, based on its structure, function, and developmental stages (Alkhassawneh & Al Sharif, 2025). Early neuroscientific theories, such as Cajal's concept of neural connectivity and Hebb's principle of synaptic strengthening, laid the foundation for understanding how experience shapes learning.

These foundational ideas have evolved into the modern concept of neuroplasticity, which explains how the brain adapts through experience. Building on this concept, Ehrlich (2022) described experience-based synaptic strengthening as a mechanism through which repeated learning reinforces neural connections. This view is supported by continuing advances in the physiology of memory and learning, which further elucidate the neural processes underlying cognitive development (Lu et al., 2023). Neuroplasticity refers to the brain's ability to form new axons, dendrites, and synapses in response to environmental changes, cognitive demands, behaviors, and emotions (Yepes Landinez et al., 2024). Building on this concept, Caine and Caine (1991), who introduced the principles of BBL, provided a crucial foundation for educational reform by emphasizing the alignment of teaching methods with the brain's natural learning processes. Over the past three decades, their ideas have inspired educators worldwide to adopt learning strategies aligned with how the brain functions, creating more effective, meaningful learning experiences for students.

Although previous studies have shown BBL's potential to enhance vocabulary acquisition, memory retention, conceptual understanding, and classroom engagement in Indonesia and the Philippines, several gaps remain. Most studies have focused on student learning outcomes from BBL teaching (Diquit et al., 2024; Fitri, 2023; Winantaka et al., 2024) rather than pre-service teachers' implementation and perceptions of BBL. Moreover, findings on BBL effectiveness remain inconsistent. While Lagoudakis et al. (2022) reported that BBL was more effective than conventional instruction in promoting student engagement, its effect on academic achievement was comparable to traditional approaches. Existing studies have also been conducted primarily within single-country contexts (Funa et al., 2024), providing little comparative evidence between Indonesia and the Philippines. These gaps highlight the need to investigate how pre-service teachers implement BBL in authentic classrooms and how it influences students' language learning across different educational settings. To bridge neuroscience and classroom practice, BBL translates principles such as neuroplasticity, hemispheric specialization, and pattern recognition into instructional strategies, including activating prior knowledge, contextual learning, active engagement, and reflective practice (Caine & Caine, 1991; Jensen, 2008). Furthermore, BBL promotes meaningful learning through contextual experiences, active participation, and collaborative interaction, resulting in stronger long-term retention compared to conventional teacher-centered approaches that rely heavily on rote memorization (Al-Hajaya et al., 2025; Mohamed & AbdElwahed, 2024). These findings suggest that BBL offers an effective pedagogical framework for enhancing language learning.

This study investigates how pre-service teachers in Indonesia and the Philippines perceive and implement the BBL approach, examines the challenges they encounter during its implementation, and evaluates its impact on students' language achievement. By integrating quantitative data on learning outcomes with qualitative insights into pre-service teachers' experiences, this cross-national study contributes to the growing field of neuroeducation by elucidating how BBL principles are interpreted and applied across two comparable yet contextually distinct Southeast Asian educational systems. The findings are expected to inform teacher education programs and support the development of more effective brain-compatible language instruction.

Conception of Brain-Based Learning

BBL is grounded in advances in cognitive neuroscience, which explain that the brain's left and right hemispheres process information in complementary ways. The left hemisphere supports

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logical, analytical, and sequential thinking, while the right hemisphere emphasizes holistic, emotional, and experiential processing (Garbutt, 2022; Morton, 2020). These complementary functions influence how individuals learn and provide a neurological foundation for designing effective instructional strategies. BBL is an instructional approach that leverages knowledge of how the brain processes, stores, and retrieves information to enhance learning (Harper, 2024; Jensen, 2008; Rodgers & Hales, 2021). Rather than functioning solely as a theoretical framework, BBL offers practical guidance for designing student-centered, brain-compatible learning environments that promote meaningful engagement and improve learning outcomes.

Empirical studies have reported BBL's effectiveness in language acquisition. Previous research shows that BBL enhances reading comprehension (Kohar, 2022), language achievement (Iram et al., 2025), and knowledge retention compared with conventional instruction (Rahman & Ajineh, 2025). Additionally, hemispheric differences shape students' language-learning strategies, with cognitive and metacognitive approaches varying by brain dominance (Suwarto & Hidayah, 2023). These findings suggest that instruction aligned with brain functioning can improve both learning processes and academic performance.

The theoretical foundation of BBL is further elucidated through twelve principles proposed by Caine and Caine, which describe learning as an interaction among cognitive, emotional, and physiological processes. These principles emphasize pattern recognition, emotional engagement, contextual learning, and integrating focused attention with peripheral perception to foster meaningful, long-lasting learning. They are operationalized through three core instructional principles: relaxed alertness, which creates a safe yet challenging learning environment; orchestrated immersion, which engages learners in authentic and meaningful experiences; and active processing, which encourages reflection and knowledge consolidation. Collectively, these principles provide a comprehensive framework for designing brain-compatible language instruction.

The Importance of Students' Perception

Students' perception refers to the cognitive process by which learners interpret and evaluate their learning experiences, drawing on prior knowledge, beliefs, and contextual factors. Grounded in cognitive and constructivist learning theories, perception reflects how students construct meaning from instructional practices rather than merely responding to them. This study examines students' perceptions through their evaluations of the BBL approach, including instructional practices, learning engagement, and perceived learning effectiveness, offering insight into how learners experience and interpret brain-compatible instruction.

Students' perceptions are a crucial indicator of instructional effectiveness because they influence motivation, engagement, and academic achievement (Fadhilah & Warni, 2024; Hakkarainen et al., 2024). Positive perceptions of teachers' instructional practices also provide valuable feedback for enhancing teaching quality and responsiveness to students (Kim et al., 2024). In the context of BBL, students who perceive BBL as meaningful and relevant are more likely to participate actively in learning and develop a deeper understanding (Pradhan et al., 2024). Therefore, examining students' perceptions complements achievement data by showing how learners respond to BBL and whether its principles foster meaningful, engaging, student-centered learning experiences.

Neuroeducation as the Theoretical Foundation of Brain-Based Language Learning

Neuroeducation integrates neuroscience, cognitive science, and educational psychology to explain how brain processes, such as emotion, attention, memory, and cognition, influence learning (Coumans & Wark, 2024; Tokuhama-Espinosa, 2024; Toomarian et al., 2024). Advances in neuroimaging and neurophysiological technologies, including fMRI and EEG, have deepened our understanding of the neural mechanisms underlying learning, memory, attention, and decision-making (Amini et al., 2024). In language education, neuroeducation provides the theoretical foundation for BBL, which applies neuroscience principles to pedagogical practices that foster meaningful, emotionally engaging, and context-rich learning experiences.

This study is grounded in the intersection of hemispheric specialization and BBL. Research on hemisphericity suggests that the left hemisphere primarily supports logical, analytical, and sequential processing, whereas the right hemisphere facilitates holistic, emotional, and experiential learning (Berlucchi, 2025). Building on these insights, Caine and Caine's twelve BBL principles conceptualize learning as a holistic interaction of cognitive, emotional, and physiological processes. Empirical evidence indicates that BBL enhances critical and creative thinking, student engagement, academic achievement (Iranmanesh et al., 2021; Nurasiah et al., 2022; Shareef-Trudeau et al., 2025), and language learning through meaningful and authentic experiences (Park et al., 2024; Wilson et al., 2023). Consequently, BBL provides a robust theoretical framework for examining how neuroscience-informed instructional strategies can improve pre-service teachers' teaching practices and students' language learning outcomes in Indonesia and the Philippines.

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Building on this foundation, the present study examines students' perceptions of pre-service teachers' implementation of the BBL approach, compares BBL with conventional instruction in enhancing students' language achievement, and explores pre-service teachers' perceptions, challenges, and the contextual factors that influence BBL implementation in Indonesia and the Philippines. By integrating both quantitative and qualitative data, this study contributes to the expanding field of neuroeducation by demonstrating how brain-compatible teaching principles are applied across two comparable Southeast Asian educational contexts. To achieve these goals, this study poses two research questions:

1. How do students perceive the implementation of the BBL approach by Indonesian and Filipino pre-service teachers, and how are these perceptions related to their learning outcomes?
2. To what extent is the BBL approach effective in improving students' language proficiency compared to conventional instruction in Indonesia and the Philippines?
3. What are the perceptions, challenges, and factors influencing the teaching performance of Indonesian and Filipino pre-service teachers in implementing the BBL approach?

METHOD

Research Design

This study employed a mixed-methods approach using a sequential explanatory design, in which quantitative data collection and analysis were followed by a qualitative phase to explain and contextualize the quantitative findings (Creswell & Creswell, 2017; Ivankova, 2014). This design was chosen to capture both the measurable effects of BBL and the instructional processes underlying its implementation, thereby providing a comprehensive understanding of teaching practices and learner responses. In the quantitative phase, we used a one-group pre-test–post-test pre-experimental design to evaluate BBL's effectiveness on students' language achievement. Students completed a pre-test before the instructional intervention and a post-test after. Additionally, a structured questionnaire was administered to assess their perceptions of BBL-based instruction. The quantitative data were analyzed using descriptive statistics, Pearson correlation, and paired-samples t-tests to examine students' achievement gains, perceptions, and the relationships among the study variables.

The qualitative phase followed the quantitative analysis to explain the statistical findings. The study conducted semi-structured interviews with purposively selected pre-service teachers representing different levels of teaching performance, as identified in the quantitative results. These interviews explored participants' perceptions, implementation experiences, and challenges in applying BBL. To complement the interview data, non-participant classroom observations were conducted using a structured observation protocol to examine instructional practices and teaching performance (Cohen et al., 2002). Finally, quantitative and qualitative findings were integrated during the interpretation stage. Qualitative evidence was used to explain and elaborate on the quantitative results, particularly the factors influencing students' learning outcomes, perceptions, and the implementation of BBL. This integration strengthened the findings' credibility through methodological triangulation and provided a more comprehensive understanding of BBL implementation across various educational contexts.

Participants

Using purposive sampling, this study involved 30 pre-service teachers undertaking their teaching practicum in six junior high schools and six senior high schools across Indonesia and the Philippines. The practicum was conducted in 12 classes, with class sizes ranging from 27 to 37 students. In total, 322 students aged 13–17 years participated in the study, representing approximately 36% of the 900 students enrolled across the participating schools. The 30 pre-service teachers were assigned to the 12 participating classes, with two or three pre-service teachers teaching each class throughout the practicum period. Each pre-service teacher independently planned and implemented BBL-based lessons, allowing researchers to observe individual teaching practices while minimizing overlap in instruction. This arrangement ensured researchers could evaluate each teacher's BBL implementation independently in an authentic classroom setting.

Participants were selected using predefined inclusion criteria. Pre-service teachers were eligible if they (1) were officially enrolled in the teaching practicum, (2) had completed BBL training provided prior to the practicum, (3) implemented BBL principles during their English language instruction, and (4) agreed to participate in classroom observations and semi-structured interviews. Student participants were included if they (1) were enrolled in the participating English classes, (2) received instruction from the participating pre-service teachers throughout the intervention period, (3) completed the required learning activities and language assessments, and (4) provided informed consent, together with parental or school consent where required. For the qualitative phase, pre-service teachers were purposively selected to represent diverse levels of instructional performance and implementation experiences, ensuring variation in the challenges and successes reported during BBL

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implementation. All participants provided informed consent for the use of their learning outcomes, classroom observations, and interview data for research purposes.

Instruments

To collect both quantitative and qualitative data, this study employed tests, a questionnaire, and semi-structured interviews. The pre-test and post-test were developed by the pre-service teachers based on language assessment principles proposed by Brown (2010), particularly emphasizing validity, reliability, practicality, authenticity, and washback. The test items were constructed using a test blueprint that covered key learning objectives, especially students' reading comprehension and understanding of instructional materials aligned with the BBL approach. The pre-test was administered before the instructional period to assess students' baseline understanding, while the post-test was conducted after the intervention to evaluate the effectiveness of the instructional approach.

For non-test data, a perception questionnaire was utilized to capture students' responses to the teaching practices of pre-service teachers employing this approach. This study grounds perception in cognitive and constructivist theories, which view perception as an individual's process of interpreting and assigning meaning to learning experiences based on prior knowledge and contextual stimuli. Based on this theoretical foundation, the questionnaire was designed to measure students' interpretations, evaluations, and responses toward instructional practices. The instrument consisted of 21 items measured on a five-point Likert scale. These constructs were operationalized as measurable statements reflecting students' perceptions of the instructional practices implemented by the pre-service teachers. Student responses were categorized into five levels based on their mean scores: 4.20–5.00 ("strongly agree"), 3.40–4.19 ("agree"), 2.60–3.39 ("neutral"), 1.80–2.59 ("disagree"), and 1.00–1.79 ("strongly disagree").

To ensure construct validity, the concept of "students' perceptions" in this study was theoretically grounded as a multidimensional construct encompassing cognitive, affective, and behavioral components. Cognitively, perception refers to students' evaluations of instructional clarity and usefulness; affectively, it reflects emotional responses such as interest, motivation, and enjoyment; and behaviorally, it relates to students' engagement and participation in learning activities. This conceptualization is consistent with established perspectives in educational psychology, which view perception as an integrated response to instructional experiences. Based on this framework, the questionnaire items were systematically mapped onto key dimensions of BBL, including meaningful learning, emotional engagement, active participation, and contextualized instruction. This alignment ensures the instrument captures more than general opinions and accurately represents theoretically defined aspects of perceptions related to BBL implementation.

To further strengthen validity, specialists in language education and educational psychology reviewed the questionnaire to ensure content relevance and alignment with the theoretical constructs. Following this, all research instruments were subjected to statistical validation and reliability testing using SPSS to ensure the accuracy and consistency of the collected data. The questionnaire items demonstrated strong validity based on item-total correlation ($r = 0.851–0.870 > r\text{-table } 0.381$; $p < 0.05$). The instrument's internal consistency was assessed using Cronbach's Alpha, yielding a coefficient of 0.972, indicating very high reliability. In addition to statistical validity and reliability, the instrument's construct validity was strengthened by aligning theoretical definitions of perception with the operational indicators measured in the questionnaire. Additionally, seven semi-structured interview questions were used to explore pre-service teachers' perceptions, challenges, and supporting factors in implementing the BBL approach. The interview protocol was developed based on qualitative interview design guidelines suggested by Kallio et al. (2016), ensuring alignment with the research objectives and allowing for in-depth exploration of participants' experiences.

Procedures

This study followed a sequential mixed-method procedure aligned with the research questions. First, data on students' perceptions of the implementation of the BBL approach were collected using a 21-item questionnaire. The instrument was tested for validity and reliability prior to analysis. The study then analyzed perception scores using descriptive statistics and correlated them with students' learning outcomes using Pearson's correlation to examine the relationship between students' perceptions and their achievement. Second, students' learning outcomes were measured through pre-test and post-test scores. The data were summarized using descriptive statistics and further examined using a paired-sample t-test to determine whether the BBL approach improved students' language proficiency compared to their baseline performance. Third, the study collected qualitative data through semi-structured interviews with pre-service teachers to explore their perceptions, challenges, and the factors influencing implementation of the BBL approach. The interview data were interpreted thematically. In addition, classroom observation results and teaching performance scores assessed by supervising lecturers were reviewed to complement and validate the qualitative findings. Finally, the integration of

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quantitative and qualitative findings was conducted at the interpretation stage. The qualitative results were used to explain, support, and provide deeper insights into the quantitative findings, ensuring triangulation and a comprehensive understanding of the implementation of BBL in both contexts.

Data Analysis

The questionnaire and test data were analyzed using descriptive statistics, including mean and standard deviation, to summarize students' scores. Students' perception data came from a 5-point Likert-scale questionnaire and were aggregated into composite mean scores across items. Although individual Likert items are ordinal, the composite scores were treated as interval-level data, which is a common practice when multiple items represent a single construct. Students' learning outcomes were measured using continuous pre-test and post-test scores. Given these data characteristics, Pearson correlation analysis was used to examine the relationship between students' perceptions of pre-service teachers' implementation of the BBL approach and their learning outcomes. Statistical significance was set at $p < 0.01$. To assess the effect of BBL implementation, pre-test and post-test scores were compared using a paired-samples t-test with a 95% confidence level. A statistically significant improvement in students' performance was indicated by $p < 0.01$. For the qualitative data, interview results were analyzed using thematic analysis to provide explanatory support and deeper insights into the quantitative findings.

FINDINGS

To explore students' perceptions of how pre-service teachers implemented BBL-based strategies, a questionnaire was administered to 322 participants, representing 36% of the 900 participants. In this study, students' perceptions are interpreted as reflecting their cognitive evaluations, emotional responses, and engagement behaviors toward the BBL-based instructional practices implemented by pre-service teachers. The questionnaire results were then compared with the students' learning outcomes. The distribution of learners' perceptions regarding BBL-based instruction by the pre-service teachers is presented in Table 1.

Table 1

The Distribution of Learners' Perceptions Regarding BBL-Based Instruction

Item BBL	SD(1)%	D(2)%	N (3)%	A (4)%	SA(5)%	Total %
1	5 (2%)	3 (1%)	11 (3%)	176 (55%)	127 (39%)	322 (100%)
2	5 (2%)	4 (1%)	21 (7%)	165 (51%)	127 (39%)	322 (100%)
3	4 (1%)	3 (1%)	19 (6%)	179 (56%)	117 (36%)	322 (100%)
4	4 (1%)	4 (1%)	54 (17%)	163 (51%)	97 (30%)	322 (100%)
5	7 (2%)	2 (1%)	16 (5%)	122 (38%)	175 (54%)	322 (100%)
6	6 (2%)	2 (1%)	28 (9%)	158 (49%)	128 (39%)	322 (100%)
7	6 (2%)	6 (2%)	34 (11%)	153 (47%)	123 (38%)	322(100%)
8	4 (1%)	4 (1%)	27 (9%)	165 (51%)	122(38%)	322 (100%)
9	5 (2%)	5 (2%)	33 (10%)	171 (53%)	108 (33%)	322 (100%)
10	6 (2%)	7 (2%)	40 (13%)	188 (58%)	81 (25%)	322 (100%)
11	4 (1%)	8 (3%)	51 (16%)	178 (55%)	81 (25%)	322 (100%)
12	6 (2%)	5 (2%)	33 (10%)	176 (55%)	102 (31%)	322 (100%)
13	5 (2%)	4 (1%)	39 (12%)	176 (55%)	98 (30%)	322 (100%)
14	3 (1%)	2 (1%)	34 (10%)	153 (48%)	130 (40%)	322 (100%)
15	1 (1%)	5 (2%)	21 (6%)	189 (59%)	104 (32%)	322 (100%)
16	6 (2%)	9 (3%)	36 (11%)	160 (50%)	111 (34%)	322 (100%)
17	6 (2%)	10 (3%)	29 (9%)	183 (57%)	94 29%)	322 (100%)
18	4 (1%)	9 (3%)	36 (11%)	168 (52%)	105 (33%)	322 (100%)
19	5 (2%)	4 (1%)	10 (3%)	127 (39%)	176 (55%)	322 (100%)
20	3 (1%)	4 (1%)	9 (3%)	150 (47%)	156 (48%)	322 (100%)
21	3 (1%)	1 (1%)	21 (6%)	156 (48%)	141 (44%)	322 (100%)
Total	98 (1,5%)	101 (1,5%)	602 (9%)	3456 (51%)	2503 (37%)	322 (100%)

Based on the analysis of students' responses to the 21 questionnaire items presented in Table 1, it was found that 51% of the 322 students expressed a positive perception by selecting the "agree" option regarding the implementation of BBL-based instruction by pre-service teachers. The most frequently agreed-upon items were Item 15 and Item 10, with 189 students (59%) affirming that pre-service teachers helped them absorb information gradually through patterning. Meanwhile, 188 students (58%) agreed with Item 10, indicating that pre-service teachers encouraged them to think more deeply about the material (mindful learning). In addition, 37% of the students expressed a highly positive perception by choosing "strongly agree," particularly for Items 19 and 5. Item 19 revealed that pre-service teachers had successfully created an enjoyable and meaningful learning atmosphere. In contrast, Item 5 emphasized their ability to build an engaging and motivating environment before the lesson began. On the neutral or uncertain side, 9% of students felt that pre-service teachers were not

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assertive enough in applying BBL principles, especially in Items 4 and 11.

Furthermore, 17% of students believed that pre-service teachers did not explicitly stimulate their curiosity at the start of the lesson or connect the material to their own experiences. Only 1.5% of students responded negatively by selecting "disagree," stating that the pre-service teachers did not provide activities that helped them link theory with practice. Similarly, another 1.5% chose "strongly disagree," particularly on Item 5, indicating they felt unmotivated to learn because the lesson began without an engaging atmosphere. As a key finding, these results indicate that most students (88%) held positive to highly positive perceptions of the BBL-based teaching practices employed by pre-service teachers. This was particularly evident in patterning, mindful learning, and creating meaningful, enjoyable learning environments. However, a small portion of students expressed uncertainty or felt that pre-service teachers did not consistently apply BBL principles.

To clarify BBL implementation in the classroom, instructional practices were analyzed across key teaching stages. During lesson introductions, pre-service teachers activated students' prior knowledge through guiding questions and contextual examples, reflecting the principle that meaningful learning builds on existing experiences. In the main instructional phase, teachers organized content to promote pattern recognition, meaningful learning, and collaborative problem-solving while fostering supportive classroom interactions. However, these strategies were applied inconsistently. Some teachers struggled to sustain student engagement, facilitate reflection, and connect learning to authentic contexts, suggesting that BBL was often implemented procedurally rather than as a fully integrated pedagogical framework.

Given the variations in classroom implementation, students' perceptions of BBL were expected to correlate with their academic achievement. To examine this relationship, a Pearson correlation analysis was conducted using students' mean perception scores and post-intervention learning achievement. The descriptive statistics for both variables are presented in Table 2.

Table 2
The Mean Scores for Both Perception and Academic Performance

Participants	Means of Perception of PSTs' BBL teaching	Means of Learning Achievement
27	89.33	73.93
23	90.17	75.43
20	86.10	75,00
28	88.82	66.14
26	85.73	72.38
37	90.59	70.49
22	90.73	74.50
20	84.50	77.75
35	88.20	67.94
36	92.22	67.39
24	83.29	71.00
24	86.00	73,96
Mean	87.97	71.70
Category	very positive	sufficient

Table 2 shows that students' perceptions of BBL-based instruction delivered by pre-service teachers were generally very positive (M = 87.97), reinforcing the findings from the previous questionnaire analysis. However, this high level of perception did not directly correlate with student learning outcomes (M = 71.10). The Pearson correlation test revealed a significance (2-tailed) value of .276, which is greater than p = 0.05, and an r-value lower than the critical r-value (.343 < .576). This indicates no significant relationship between perception and learning outcomes. This finding reveals a discrepancy between students' positive perceptions and their actual learning outcomes. Although students reported high engagement and enjoyment, these positive affective responses did not translate into significant academic gains. This inconsistency may be attributed to the partial implementation of Brain-Based Learning (BBL), where essential principles such as reflection, pattern recognition, and meaningful consolidation were not consistently integrated into classroom practice. Moreover, pre-service teachers' limited understanding of neuroeducation principles, coupled with neuromyths, insufficient practical training, and institutional constraints, such as limited instructional time, curriculum demands, and inadequate mentoring, likely reduced the fidelity of BBL implementation. These findings suggest that positive student perceptions alone are insufficient to improve academic achievement unless BBL principles are implemented comprehensively and consistently.

Effectiveness of the BBL approach

To evaluate the impact of the BBL approach, 30 pre-service teachers administered a pre-test in 30 junior and senior high school classes, each comprising 30 students. After determining that students' low academic performance was attributable to conventional teaching methods, the

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study had all students participate in an intervention using the BBL approach over four sessions. Following this instructional intervention, a post-test was conducted to assess the effect of BBL on students' language comprehension and skills. The mean pre-test scores were then compared with the mean post-test scores using a paired sample t-test. As this test is a parametric statistical procedure, the data must be normally distributed. The One-Sample Kolmogorov-Smirnov Test yielded a p-value of 0.200 > 0.05, indicating that the residual data are statistically normally distributed. The Paired-samples test results are summarized in Table 3.

Table 3.
Summary of Students' Language Proficiency Gains Across Pre-Service Teachers

Statistic	Value
Number of pre-service teachers	30
Students per class	30 (one class had n = 29)
Classes with significant improvement	30 (100%)
Mean gain score (range)	2.23–22.20
Mean *t* value (range)	−5.47 to −94.93*
Significance	All $p < .001$

Results indicated statistically significant improvements in all classes ($p < .001$). Mean gain scores ranged from 2.23 to 22.20 points, demonstrating BBL's consistent positive effects on students' language proficiency across classroom contexts. A key novelty of this study is identifying an implementation gap among pre-service teachers. Although 57% showed low mastery of BBL principles, they inadvertently applied several BBL strategies in classroom practice. This suggests a discrepancy between implicit practice and explicit pedagogical knowledge, underscoring the need for improved training programs that address both the theoretical and practical dimensions of BBL. The complete teacher-specific paired-samples *t*-test results are provided in Appendix A.

From a neuroeducation perspective, pre-service teachers' challenges, such as stimulating curiosity, promoting long-term retention, sustaining learner engagement, and designing emotionally meaningful and enjoyable learning experiences, indicate a limited understanding of how the brain processes, retains, and responds to information. These challenges highlight limited awareness of activating brain-compatible elements, including emotional safety, pattern recognition, novelty, and multisensory input, all of which are essential for effective brain-based instruction. Therefore, targeted professional development is necessary to help pre-service teachers internalize core neuroeducational principles and create enriched, brain-friendly learning environments that support both cognitive and emotional development.

Perceptions, Challenges, and Teaching Performance in the BBL Approach

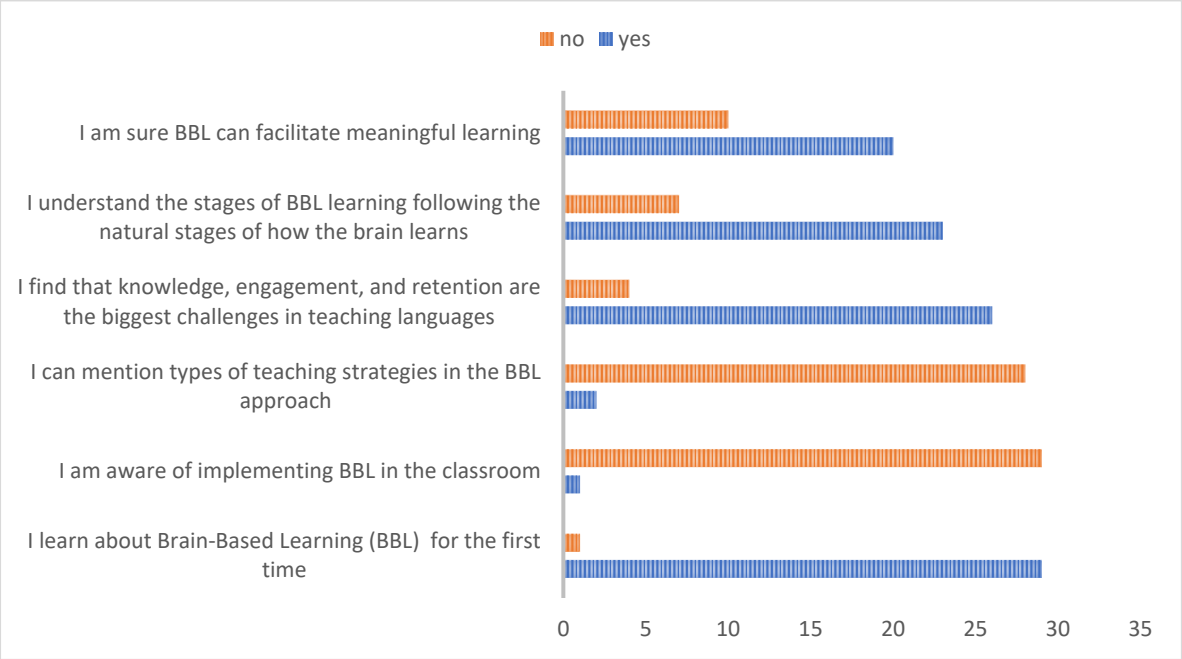
To explore pre-service teachers' perceptions and challenges regarding BBL, the researcher conducted interviews with 30 participants, each responding to six semi-structured questions. The interview questions focused on two main themes related to implementing BBL-based instructional strategies. The first theme addressed the participants' perceptions of their knowledge and understanding of BBL principles, while the second explored the challenges they encountered in applying these strategies. The interview results are essential for cross-checking the alignment between observed phenomena and the theoretical foundations of BBL-based learning. The findings related to pre-service teachers' perceptions of the BBL approach are presented in Figure 1.

The interview results, summarized in Figure 1, indicate that 29 participants, representing 97% of the pre-service teachers, acknowledged that they had only recently become acquainted with the term (BBL) approach. Based on classroom observations and responses to the penultimate interview question, 97% of the participants were unaware that they had already been applying the 12 principles of the BBL approach in their teaching practices. This finding highlights a discrepancy between theoretical understanding and practical implementation of instructional strategies. The participants' ability to employ various teaching strategies does not necessarily align with their knowledge of the underlying principles of these approaches. This gap is further supported by interview findings indicating that 26 participants (87%) were unable to identify any strategies explicitly based on the BBL approach, despite the fact that all participants had, in practice, implemented such strategies.

In practice, pre-service teachers faced challenges across different instructional stages. During lesson openings, some teachers struggled to effectively stimulate curiosity or create a motivating learning atmosphere, resulting in passive student responses. In the core learning activities, although teachers attempted to incorporate contextual and meaningful tasks, many failed to engage students in active knowledge construction or collaborative learning processes. Furthermore, limited opportunities were provided for reflective thinking, which is essential in BBL to support pattern recognition

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Figure 1
Distribution of Pre-Service Teachers' Perceptions of BBL



and long-term memory consolidation. In the closing stage, several teachers did not conduct formative assessments or reflective discussions, reducing opportunities for students to internalize and evaluate their learning. These findings indicate that teachers often applied BBL principles, such as meaningful learning, emotional engagement, and reflection, incompletely or inconsistently in classroom practice.

Additionally, the participants identified three primary challenges in applying BBL-based instruction: fostering students' comprehension, engaging students, and enhancing memory retention. The interview data show that 23 participants (77%) struggled with student retention and engagement, while 7 participants (23%) could not implement all three key components of the BBL approach. These three components correspond to the twelve principles that elucidate how the brain learns. Although most participants were unfamiliar with the term, nearly 28 participants recognized that the stages of language learning naturally align with these principles. Additionally, 20 participants (67%) believed the BBL approach promotes meaningful, student-centered learning because it emphasizes engagement and retention. Conversely, 10 participants (33%) maintained that conventional approaches still play a significant role in enhancing students' comprehension. In conclusion, the interview data on participants' perceptions of this approach indicate that, in general, participants have adopted teaching strategies that align with BBL principles, even if they are not familiar with the specific terminology or can't explicitly identify the strategies. Among the three core elements of BBL, participants most often reported challenges with engaging students and creating meaningful learning experiences without creating pressure.

The challenges faced by pre-service teachers in implementing the BBL approach were examined through interviews and feedback from lecturers regarding the participants' classroom teaching performance. The interview data were then categorized into thematic areas representing the main challenges and underlying sources of difficulty pre-service teachers encountered in applying the BBL approach. The distribution of pre-service teachers' challenges of BBL is presented in Table 4.

The interview results and evaluative comments from lecturers indicate that the pre-service teachers faced challenges in applying the 12 principles of BBL, which were operationalized into seven instructional aspects. In the pre-teaching phase, while 20 participants (67%) provided a clear initial overview of the lesson, 10 participants (33%) delivered introductions that were not sufficiently relevant to the core material. Regarding their ability to stimulate students' curiosity about the lesson content, only 4 participants (13%) failed to provide any encouragement. Additionally, 6 participants (20%) tried to generate interest but failed to capture students' attention, resulting in low motivation and limited participation. Regarding real-life experiences, 21 participants (70%) provided authentic learning opportunities that actively engaged students. However, 2 participants (7%) presented content misaligned with the learning objectives, while 7 participants (23%) delivered appropriate material but lacked interactivity. Furthermore, many respondents struggled to create meaningful learning experiences. The interview findings show that only 7 participants (23%)

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Table 4
Distribution of Pre-service Teachers' Challenges of BBL

No	Principles of Teaching in BBL	Poor	Fair	Good	Excellent
1	Providing an initial overview/the brain processes parts and wholes simultaneously	5	5	20	0
2	Stimulating curiosity/Learning is enhanced by challenge and inhibited by threat	4	6	19	1
3	Providing real-life experiences/Learning is most effective when it is contextual	2	7	18	3
4	Making learning more meaningful/Learning involves both conscious and unconscious processes	15	8	5	2
5	Allowing time to process information/the brain processes meaning best through patterning, and Learning involves both focused attention and peripheral perception	5	15	7	3
6	Evaluating students' understanding/learning is developmental, and each brain is uniquely organized	2	10	16	2
7	Making learning enjoyable/Emotions are critical to patterning, and Learning is enhanced by challenge and inhibited by threat	4	5	20	1
	Total /%	37 (18%)	56 (26%)	105(50%)	12 (6%)

facilitated learning that effectively promoted retention, whereas the remaining 23 participants (77%) struggled to engage students actively, resulting in passive behavior and reduced attention to the teacher's explanations. Ideally, teachers should create opportunities for students to express the target language in ways that are personally and contextually meaningful, incorporating their own experiences and social environments into the learning process.

However, in practice, only 10 participants (33%) allowed time for students to reflect, while 20 participants (67%) did not provide sufficient time for students to internalize the material. At the end of the lesson, 18 participants (60%) assessed students' learning experiences; however, 12 participants (40%) did not assess students after instruction because they struggled to allocate time for evaluation. According to Principle 12 of BBL, only 21 participants (70%) created an enjoyable learning environment, while the remaining 9 participants (30%) struggled to make lessons engaging and enjoyable. These challenges indicate that participants had not thoroughly studied or internalized BBL principles. To improve their teaching performance, the respondents received additional support on how to apply BBL principles effectively in contemporary classroom instruction.

Based on a thematic analysis of interview data on the challenges pre-service teachers face in understanding and implementing the 12 BBL principles, the study identified two significant weaknesses in their language teaching practices: an inability to foster meaningful learning and a lack of reflective pauses. This suggests that respondents had not yet recognized that learning involves both conscious and unconscious brain processes. Theoretically, meaningful content engages both the brain's cognitive and emotional systems, facilitating deeper, more enduring learning. Reflective pauses are essential because the brain processes meaning most effectively through pattern recognition. Learning is enhanced by both focused attention and peripheral perception. From a neuroeducation perspective, allowing processing time helps learners identify patterns and connect ideas, honoring the brain's intrinsic need for integration and consolidation. These findings highlight that implementing BBL in classroom settings requires not only procedural application of teaching strategies but also a deep conceptual understanding of how the brain learns. The gap between implicit practice and explicit knowledge suggests that teacher education programs should emphasize translating neuroeducational principles into structured pedagogical actions, including lesson design, student engagement techniques, and reflective learning practices.

After identifying the participants' perceptions of BBL and the challenges they face in implementing BBL-based instructional strategies, this study evaluated the participants' teaching performance, as assessed by nine lecturers. The assessment rubric utilized a scale from 1 to 5, encompassing seven teaching aspects derived from the principles of BBL instruction. Each teaching aspect included five statements representing the themes associated with that aspect, ranging from least to most comprehensive. Consequently, the scoring range extended from 1 to 35. The output of descriptive statistics is presented in Table 5. Based on the data, the 30 participants' teaching performance showed moderate variability, with most scoring around the average of 28.43. The data indicate generally good performance; however, the range and standard deviation reveal that while some participants excelled, others scored significantly lower, reflecting inconsistencies in teaching quality or comprehension of the measured approach.

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Tabel 5
The Output of Descriptive Statistics on Participants' Teaching Performance through the BBL Approach

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Teaching performance	30	11	23	34	853	28.43	3.234	10.461
Valid N (listwise)	30							

Sixteen participants (53%) showed fundamental weaknesses in the introduction phase of BBL principles, particularly in supporting memory retention and promoting meaningful learning. Although overall teaching performance was categorized as "good" or moderately high, only fourteen participants (47%) could initiate, explore, and conclude lessons effectively.

These stages represent fundamental principles of brain learning mechanisms, indicating that the brain does not process information all at once but rather gradually through specific patterns. This suggests that conceptual understanding of the BBL stages remains uneven, with most participants (10 out of 30) still using conventional teacher-centered approaches that fail to stimulate curiosity and promote active student engagement. The lack of effective formative assessment and insufficient reflective learning practices further underscores the finding that the implementation of Problem-Based Learning (PBL) strategies within the BBL framework has not yet been fully internalized, either pedagogically or neurologically. This study offers novel insights by revealing the gap between procedural teaching performance and BBL's neurological principles, highlighting the urgent need for deeper neuro-pedagogical integration in teacher training.

DISCUSSION

Based on the analysis of three types of data, this study addresses three primary objectives: (1) to examine students' perceptions of language instruction delivered by pre-service teachers within the educational contexts of Indonesia and the Philippines, and to investigate how these perceptions correlate with their learning outcomes; (2) to explore and analyze pre-service teachers' perceptions of the BBL approach, including the challenges and successes encountered during its implementation; and (3) to assess the effectiveness of BBL as applied by pre-service teachers in enhancing students' language performance. These three components are examined through a neuroeducational lens. Consequently, this study reveals three major findings, each interpreted from a neuroeducational perspective.

The first finding indicates that although most students reported positive perceptions of BBL instruction delivered by pre-service teachers, these perceptions were not statistically significantly correlated with learning outcomes. From a neuroeducational perspective, this suggests that positive perceptions alone are insufficient to foster deep, meaningful, and enjoyable learning if BBL principles are not applied consistently and aligned with how the brain processes information. As Stalling (2024) argues, continuous BBL training is essential to help pre-service teachers dispel neuromyths. In his dissertation, he emphasizes that equipping pre-service teachers with practical BBL strategies improves their understanding of optimal BBL and strengthens their future pedagogical support. Harper (2024) further underscores the need for a more balanced approach that integrates both analytical and creative strategies to promote critical thinking and holistic development, ultimately fostering more dynamic learning environments. Supporting this, Abdolmaleki and Saeedi (2024) reported that participants had positive experiences with brain-based teaching strategies, which improved their instructional quality and contributed to better student achievement.

The implementation of BBL was also shaped by contextual differences between Indonesia and the Philippines. In Indonesia, curriculum mandates and assessment-oriented practices emphasized content coverage and exam preparation, limiting opportunities for reflective, student-centered learning. In contrast, in the Philippines, although more flexible and communicative approaches were encouraged, cultural factors such as students' deference to teacher authority sometimes constrained active participation and critical engagement. These contextual differences indicate that BBL implementation challenges are not uniform but are shaped by distinct institutional and socio-cultural conditions in each country.

The second finding reveals that although most pre-service teachers have used strategies aligned with BBL principles, they still struggle to create meaningful learning experiences and provide reflective pauses during instruction. Most of these teachers have not yet developed a deep understanding of neuroeducation, despite having unconsciously implemented BBL strategies that support improved student outcomes. Pradeep et al. (2024) noted that pre-service teachers often overlook the importance of integrating the brain's conscious and subconscious processes in facilitating retention and meaning-making. This observation aligns with Pradeep's earlier conclusion that, from a neuroeducational perspective, the brain requires adequate processing time to recognize patterns and build deep interconceptual connections. In contrast,

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Elton (2018) observed that many practitioners implementing brain-based models explore creative and imaginative approaches to teaching and learning without grounding their practices in neuroscience, often because they are reluctant to engage with the scientific aspects. Conversely, Winantaka et al. (2024) emphasized that integrating project-based learning, audiovisual methods, and critical thinking within BBL supports a balance between right- and left-brain functions in the learning process.

The third finding indicates that the BBL approach significantly improves students' learning outcomes. However, this study also reveals a critical gap between pre-service teachers' procedural skills in implementing BBL and their understanding of the neurological principles underlying its key phases, namely, lesson introduction, information retention, and closure. When pre-service teachers balance understanding the principles and application of BBL, the learning process, student engagement, and academic outcomes become more enjoyable, meaningful, and memorable. These results align with the findings of Kaewkumsai and Phusee-orn (2024), who demonstrated that BBL-based instruction in basic logic significantly enhances student performance and satisfaction. From a neuroeducational perspective, Handayani and Corebima (2017) emphasize that BBL is grounded in cognitive theory and brain architecture, engaging critical brain structures such as the cerebellum, cerebral cortex, frontal lobe, limbic system, and prefrontal cortex. Supporting this, Fitri and Zaeni (2020) found that BBL improves students' cognitive connections. Nevertheless, this study confirms that many pre-service teachers still rely on conventional methods that fail to effectively activate the brain and lack formative assessment and reflective practices.

Collectively, these findings extend current neuroeducation literature in three important ways. First, they show that students' positive perceptions of BBL do not necessarily translate into improved achievement when instruction does not faithfully follow neuroeducational principles. Second, they reveal that many pre-service teachers implement BBL procedurally rather than conceptually, indicating a substantial gap in neuroscience-informed pedagogical knowledge. Third, they show that BBL effectiveness is shaped not only by instructional strategies but also by contextual educational conditions across Indonesia and the Philippines. These contributions provide new empirical evidence that successful BBL implementation depends on integrating neuroscience knowledge, pedagogical competence, and contextual adaptation rather than on isolated instructional techniques alone.

This study contributes to neuroeducation by examining the gap between pre-service teachers' procedural skills and their understanding of the neurological principles underlying the BBL approach. It underscores the urgent need for ongoing, neuro-pedagogically integrated training to ensure that teaching is not only technically effective but also aligned with the brain's natural learning processes, thereby fostering meaningful, reflective, and impactful educational experiences.

CONCLUSION

This study identified three key findings across Indonesia and the Philippines. First, although most students (88%) reported positive perceptions of Brain-Based Learning (BBL), these perceptions were not significantly correlated with language learning outcomes, primarily due to the partial implementation of BBL principles. Second, while pre-service teachers could apply BBL strategies procedurally, they showed limited understanding of the underlying neuroeducational principles needed to promote meaningful learning and long-term retention. Third, BBL significantly improved students' language proficiency; however, its effectiveness varied depending on teachers' conceptual understanding and instructional implementation. These findings highlight a critical gap between procedural application and conceptual knowledge in BBL implementation.

The study underscores the importance of systematically integrating neuroeducation into teacher education programs, ensuring that pre-service teachers develop both theoretical understanding and practical competence in brain-based pedagogy. Nevertheless, the study is limited by its focus on selected participants from Indonesia and the Philippines, which constrains the generalizability of the findings, and by the absence of neurocognitive and longitudinal measures to capture the development of neuro-pedagogical competencies more comprehensively. In light of these findings, several targeted recommendations are proposed. Teacher education programs should explicitly address neuro-myths through evidence-based neuroeducation training and strengthen practicum models with guided mentoring and reflective cycles to bridge the gap between procedural practice and conceptual understanding. Context-specific adjustments are also necessary: in Indonesia, training should focus on integrating BBL within assessment-driven curricula, while in the Philippines, emphasis should be placed on promoting active participation within communicative learning environments.

In light of these findings, it is recommended that teacher education institutions strengthen BBL-oriented training through a balanced integration of neuroscience theory, reflective practice, and authentic teaching experiences, thereby enabling future educators to design learning environments that are meaningful, engaging, and aligned with the brain's natural learning processes. Future research

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should adopt longitudinal and experimental designs to better examine the development and sustained impact of neuro-pedagogical competence.

AI USE ACKNOWLEDGEMENT

During the preparation of this manuscript, we used Wordvice AI Grammar Checker and Grammarly to check grammar and improve sentence clarity. The authors used these tools solely for language editing. No AI tools were used to generate scientific ideas, conduct data analysis, or interpret the results; the authors take full responsibility for the content of the article.

CONTRIBUTION OF THE AUTHORS

The first author conceptualized the study, designed the methodology, drafted the manuscript, and handled correspondence. The second and third authors contributed to data analysis and interpretation and helped revise the manuscript. The fourth author conducted the investigation in the Philippines, contributed to data analysis and interpretation, and helped revise the manuscript. The fifth author contributed to validation and visualization. The sixth author collected and analyzed the data. All authors contributed to writing, review, and editing and approved the final version of the manuscript.

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APPENDIX A

Paired-samples t-test results of students' English achievement before and after instruction by each pre-service teacher

Pre-service Teacher	Mean Difference	SD	t	df	p
1	−18.833	8.579	−12.025	29	< .001
2	−9.700	4.801	−11.067	29	< .001
3	−7.667	2.537	−16.551	29	< .001
4	−20.333	8.087	−13.771	29	< .001
5	−8.500	7.210	−6.457	29	< .001
6	−8.667	4.536	−10.465	29	< .001
7	−22.200	4.809	−25.282	29	< .001
8	−10.167	4.639	−12.003	29	< .001
9	−8.500	3.256	−14.297	29	< .001
10	−7.200	5.580	−7.068	29	< .001
11	−7.467	3.104	−13.174	29	< .001
12	−8.833	4.086	−11.841	29	< .001
13	−9.833	5.167	−10.424	29	< .001
14	−16.533	10.523	−8.605	29	< .001
15	−3.833	7.507	−17.390	29	< .001
16	−5.724	3.011	−10.239	29	< .001
17	−6.700	3.505	−10.470	29	< .001
18	−5.967	3.819	−8.557	29	< .001
19	−21.000	11.326	−10.156	29	< .001
20	−2.667	2.670	−5.471	29	< .001
21	−7.333	5.047	−7.959	29	< .001
22	−7.333	5.047	−7.959	29	< .001
23	−14.167	9.270	−8.370	29	< .001
24	−11.767	.679	−94.930	29	< .001
25	−8.133	5.923	−7.521	29	< .001
26	−2.233	1.040	−11.762	29	< .001
27	−6.433	4.345	−8.111	29	< .001
28	−5.500	4.321	−6.971	29	< .001
29	−3.133	1.358	−12.639	29	< .001
30	−2.233	1.040	−11.762	29	< .001

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