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Effect of Brain-Based Learning on Students Biology Learning Outcomes

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Abstract: Low biology learning outcomes are often linked to conventional teacher-centered instruction, which limits student engagement and active participation. This study was conducted to address these challenges by examining the effect of Brain-Based Learning on students' biology achievement. The main objective was to determine whether this innovative approach could significantly improve learning outcomes compared to traditional methods. A quasi-experimental design was employed, specifically the pretest-posttest control-group design. The sample was selected using purposive sampling, resulting in two classes: an experimental class that received Brain-Based Learning treatment and a control class that continued with conventional instruction. Data collection techniques included biology achievement tests administered before and after the intervention, complemented by classroom observations to monitor the implementation process and student involvement. Data analysis was carried out using an independent sample t-test to assess the significance of differences between the two groups. The results revealed a clear and significant effect of Brain-Based Learning on students' biology learning outcomes, as indicated by a p-value of 0.000, which is below the 0.05 threshold. The average post-test score in the experimental class was 78.45, while the control class scored only 49.32. These findings demonstrate that Brain-Based Learning is more effective than conventional methods in enhancing students' understanding of biological concepts. In conclusion, Brain-Based Learning significantly improves biology learning outcomes and fosters more active, meaningful, and engaging learning experiences. The practical implication of this study is that teachers should consider adopting Brain-Based Learning as an innovative instructional strategy to enhance the quality of biology education. By shifting from teacher-centered to student-centered approaches, educators can create learning environments that better support achievement and long-term retention of scientific knowledge.

Keywords: Biology Learning Outcomes; Brain-Based Learning; Constructivist Learning; Conventional Learning.

Introduction

Biology learning is a structured and systematic process aimed at developing students' understanding of living systems, scientific concepts, and natural phenomena through inquiry-based and evidence-driven approaches [1]. As a core component of science education, biology not only emphasizes cognitive mastery but also integrates scientific skills, critical thinking, and attitudes necessary for understanding complex life processes [2]. However, in many educational contexts, biology instruction is still dominated by teacher-centered approaches that prioritize rote memorization rather than conceptual understanding. Such practices limit students' opportunities to actively engage in meaningful learning experiences, resulting in superficial knowledge acquisition and difficulties in comprehending abstract biological concepts such as cellular processes, genetics, and ecological interactions [3]. In addition, conventional instructional strategies often neglect how the brain naturally learns, hindering students' ability to retain and apply knowledge effectively. This mismatch between instructional practices and brain functioning contributes to low learning outcomes and reduced student motivation in biology classrooms.

An alternative approach that has gained attention in addressing these challenges is Brain-Based Learning (BBL). This approach is grounded in neuroscience and emphasizes the alignment of teaching strategies with the natural processes of the human brain in receiving, processing, storing, and retrieving information [4]. Brain-Based Learning encourages the creation of a supportive and stimulating learning environment that integrates emotional engagement, active participation, and multisensory experiences [5]. By incorporating elements such as meaningful context, collaboration, reflection, and real-life connections, BBL enables students to construct knowledge more effectively and retain information longer. Concepts are abstract and require deep understanding, the application of BBL is particularly relevant [6]. It allows students to link theoretical knowledge with real-world phenomena, thereby enhancing conceptual understanding and improving learning outcomes.

Recent developments in educational research highlight the growing importance of innovative teaching strategies that are responsive to students' cognitive and neurological [7]. Brain-Based Learning has emerged as a promising approach in this regard, with numerous studies demonstrating its effectiveness in enhancing student engagement, motivation, and academic achievement [8]. Despite this growing body of research, the implementation of BBL in secondary school settings remains relatively limited, especially in biology education. Many existing studies focus on general learning outcomes or are conducted in different subject areas, such as mathematics or language

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learning. As a result, there is a lack of empirical evidence examining the impact of Brain-Based Learning on biological learning outcomes. This gap indicates the need for more focused research investigating the effectiveness of BBL in the specific context of biology instruction, particularly at the secondary school level [9].

Several studies conducted in the last five years provide strong support for the effectiveness of Brain-Based Learning in improving student learning outcomes reported that instructional strategies aligned with brain principles significantly enhance students' retention and comprehension of complex material [10]. Emphasized that emotional engagement and a positive learning environment play a crucial role in facilitating memory formation and knowledge retention [11]. Furthermore, highlighted that integrating neuroscience principles into teaching practices can improve student motivation, engagement, and overall academic performance [12]. Also found that brain-based instructional approaches strengthen cognitive processing and support deeper learning. In addition, recent empirical studies in science education have demonstrated that BBL contributes to improved conceptual understanding and higher-order thinking skills among students [13]. These findings suggest that Brain-Based Learning is not only theoretically sound but also practically effective in enhancing educational outcomes across various contexts.

Although previous studies have shown positive results, there is still a need to expand research that specifically focuses on the application of Brain-Based Learning in biology education. Many studies have not fully explored how BBL influences different dimensions of biology learning outcomes, including conceptual understanding, retention, and application of knowledge [14]. Moreover, contextual factors such as classroom environment, student characteristics, and instructional design are often not adequately addressed in existing research [15]. Strengthening research in this area is essential to provide more comprehensive insights into the effectiveness of Brain-Based Learning and its practical implications for teaching biology. By conducting more targeted and context-specific studies, researchers can contribute to the development of evidence-based instructional strategies that are better alsigned with students' learning needs [16].

The objective of this study is to determine the effect of Brain-Based Learning on students' biology learning outcomes and to analyze how this approach contributes to improved conceptual understanding and academic performance. This study is expected to provide empirical evidence that supports the implementation of Brain-Based Learning as an effective instructional strategy in biology education. Furthermore, the findings of this study are anticipated to offer practical implications for teachers in designing more engaging, innovative, and neuroscience-informed learning environments that enhance student learning outcomes.

Research Methods

This study employed a quasi-experimental research design. This design aims to test cause-and-effect relationships involving an experimental and a control group. The experimental class was taught using the Brain-Based Learning (BBL) model.

while the control class was taught using conventional learning methods. This research was conducted from October to November 2025 at SMAN 8 Mataram in the 2025/2026 academic year. The population in this study consisted of grade X students of SMAN 8 Mataram in the 2025/2026 academic year. The total number of grade X students at SMAN 8 Mataram is 384 people spread across 12 classes.

Sampling in this study was conducted using a purposive sampling method to determine the control and experimental classes. Purposive sampling is a sampling technique that prioritizes certain criteria and research objectives [6]. This method was used to select four classes as control and experimental groups based on similar cognitive abilities and the fact that they were taught by the same teacher. The sampling process was based on pretest results that did not differ significantly and the similarity of the teaching teachers. The selected sample consisted of students in classes XE1, XE2, XE3, and XE4. After the sample classes were determined, a lottery was held to determine the experimental and control groups. The lottery results showed that classes XE1 and XE2 were designated as the experimental groups, while classes XE3 and XE4 served as the control groups.

This study involved four classes, consisting of two experimental classes and two control classes, and used a pre-test–post-test control group design. As explained, the first group consisted of classes that used the Brain-Based Learning model and served as the experimental group, while the second group consisted of classes taught using conventional learning methods and served as the control group.

The data in this study were collected by administering a pre-test to both the experimental and control classes at the beginning of the meeting. Next, treatment was administered using the Brain-Based Learning model in the experimental class and conventional learning methods in the control class. At the end of the meeting, a post-test was administered to each class to determine the effect of the learning model. In this study, learning outcomes focused on the cognitive domain. Cognitive learning outcome data were collected via a written multiple-choice test.

The data obtained from the pre-test and post-test were analyzed using the IBM SPSS Statistics version 26 program. The data analysis procedures included normality tests, homogeneity tests, and hypothesis tests using Analysis of Covariance (ANCOVA) in IBM SPSS Statistics 26. This analysis was conducted to determine the effect of the Brain-Based Learning model on the biology learning outcomes of class X students at SMAN 8 Mataram.

Results and Discussion

Based on the results of the initial learning outcome test given to four classes, the data shows that the experimental class obtained an average pre-test score of 49.32, which is categorized as sufficient.

Meanwhile, the control class obtained an average pre-test score of 42.37, which is also categorized as sufficient. After the treatment, the four sample classes were given a post-test consisting of the same multiple-choice questions as the pre-test. Post-test data showed that the experimental class had a higher average score than the control class. The experimental class achieved an average post-test score of 78.45, which is categorized as good, while the control class achieved an average post-test score of 49.32, which is also categorized as good.

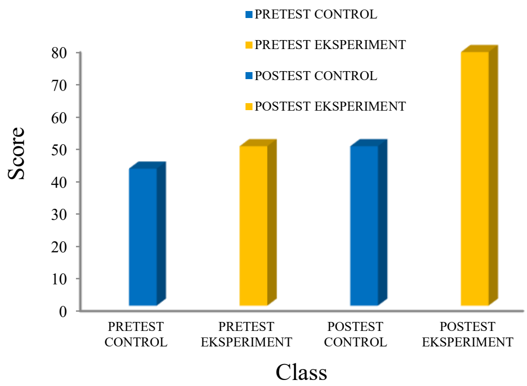

Figure 1. Comparison of the Average Pre-test and Post-test Scores of the Four Sample Classes.

A comparison of the pre-test and post-test results in the experimental and control classes showed an increase in learning outcomes in all four classes after the treatment. Pre-test data indicated that the average score in the experimental class was higher at 49.32 than in the control class at 42.37.

Table 1. Results of the Normality Test of Learning Outcomes

	Class	Stat.	df	Sig.
Learning Completion Results	Pre-test Control	0.965	64	0.145
	Post-test Class Control	0.966		64 0.312
	Pre-test Eksperimen	0.966	64	0.493
	Post-test Eksperimen	0.968	64	0.272

Based on the results of the normality test for pre-test and post-test scores in both the control and experimental classes, the significance values (Sig.) obtained were 0.070 and 0.077 for the control class, and 0.071 and 0.096 for the experimental class. All significance values exceeded the 0.05 threshold, indicating that the student learning outcome data In both classes, the pre-test and post-test data were normally distributed.

Table 2. Results of the Homogeneity Test of Learning Outcomes

		Levena statistics	dfl	df2	Sig.
Scor	Average value	1.058	11	126	0.360

The results of the homogeneity test show that the significance value based on the average (mean) is 0.360, which is greater than 0.05. This indicates that the data from the four classes have homogeneous variance. The results of this study clearly indicate that implementing Brain-Based Learning (BBL) significantly improves students' biology learning outcomes. Based on the statistical test, the p-value was 0.000, which is lower than the 0.05 significance level. This finding confirms a significant difference in learning outcomes between students taught using the Brain-Based Learning model and those taught using conventional learning methods. Therefore, it can be concluded that BBL is more effective in enhancing students' biology learning outcomes [17-18]. Quantitatively, this improvement is reflected in the comparison between pre-test and post-test scores. In the experimental class that used BBL, the average post-test score was 78.45, while the control class achieved an average of 49.32.

Table 3. Results of the Ancova Test of Learning Outcomes

Tests of Between-Subjects Effects.					
Dependent Variable :			Poster SR		
Source	Type III Sum of Suares	df	Mean	f	Sig.
Group	6268.063	2	3134.032	29.899	0.000

This substantial difference suggests that learning approaches aligned with the brain's natural functioning are more effective at helping students understand biological concepts. This finding is consistent with Jensen, who states that brain-based learning is designed to optimize brain function through active, meaningful, and contextual learning experiences. Theoretically, Brain-Based Learning is grounded in neuroscience, which emphasizes that learning becomes more effective when it aligns with how the brain naturally works [19]. According to Caine and Caine, the brain learns best through patterning, emotional engagement, and direct experience [20]. In the context of biology learning, which often involves abstract concepts such as organ systems and complex life processes, this approach becomes highly relevant.

Students are better able to understand and retain information when they engage multiple senses and actively participate in the learning process. Sousa further explains that positive emotional involvement strengthens long-term memory, making it easier for students to retain and recall information. The effectiveness of BBL in this study is also evident in the increased student participation during the learning process [21]. This aligns with constructivist theory proposed by Piaget and Vygotsky, which emphasizes that knowledge is actively constructed by learners through interaction and experience [22]. In Brain-Based Learning, students are encouraged to explore, identify problems, seek information, and connect new knowledge with prior understanding.

This process leads to meaningful learning, as described by Ausubel, in which new information is integrated into existing cognitive structures [23]. In addition, the high learning outcomes in the BBL class are influenced by the creation of a comfortable and enjoyable learning environment. According to the emotional brain theory proposed by LeDoux, emotional conditions significantly affect the learning process [24]. A supportive and stress-free environment enhances the brain's ability to process information effectively. This is supported by research showing that learning involving emotion, reflection, and experience activates multiple brain areas, thereby strengthening conceptual understanding [25]. In biology learning, the application of BBL enables students not only to memorize concepts but also to understand processes and relationships between concepts.

For example, in learning about the coordination system, students can engage in discussions, simulations, and problem-solving activities that require active involvement. This is consistent with the principles of active learning, which emphasize that students learn more effectively when they are directly engaged in the learning process [26]. In contrast, the control class that applied conventional learning methods tended to be teacher centered. The teacher dominated the learning process, while students played a more passive role. Although learning outcomes improved, the increase was relatively small. This finding is in line with Slavin, who argues that teacher centered learning is less effective in developing critical thinking and deep conceptual understanding [27]. Similarly, states that conventional learning often focuses on knowledge transfer without providing sufficient opportunities for students to construct their own understanding.

The findings of this study are further supported by previous research. Jensen reports that Brain-Based Learning significantly improves students' cognitive achievement, particularly in science education. Brain-based approaches enhance student engagement and conceptual understanding [28]. In addition, Sousa demonstrates that instructional strategies aligned with brain function improve both retention and transfer of knowledge. Furthermore, research in biology education shows that Brain-Based Learning not only improves cognitive outcomes but also enhances affective and psychomotor domains. This is consistent with Bloom's taxonomy, which categorises learning outcomes into these three domains.

Through BBL, students develop a more comprehensive learning experience, including understanding concepts, building positive attitudes, and acquiring practical skills. Overall, this study confirms that Brain-Based Learning is an effective approach for improving biology learning outcomes. Its effectiveness is supported by principles of neuroscience, constructivist theory, and empirical research findings. The main strength of BBL lies in its ability to integrate cognitive, emotional, and experiential aspects of learning, making the process more meaningful, engaging, and effective. Therefore, Brain-Based Learning can be considered an innovative and relevant instructional strategy to improve the quality of biology education.

Conclusion

This study confirms that Brain-Based Learning has a significant and positive effect on students' biology learning outcomes. The statistical results show a clear difference between students taught using Brain-Based Learning and those taught using conventional methods, with the experimental group achieving substantially higher scores. This indicates that learning approaches aligned with how the brain naturally processes information are more effective in improving students' understanding of biological concepts. The findings also highlight that Brain-Based Learning creates a more active, meaningful, and engaging learning environment. Students are encouraged to participate actively, think critically, and connect new knowledge with prior understanding, which leads to better retention and deeper conceptual mastery. In contrast, conventional teacher centered learning tends to limit student involvement and results in lower learning outcomes. Overall, Brain-Based Learning is proven to be an effective instructional approach that not only improves cognitive achievement but also enhances student engagement. Therefore, it is recommended as an innovative strategy to improve the quality of biology education and support more student-centered learning practices.

Author's Contribution

E. Putri: Conceptualization, methodology, data collection, data analysis, writing original draft. Jamaluddin: supervision, validation, review and editing. I W. Merta: methodological guidance, data interpretation, review and editing

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