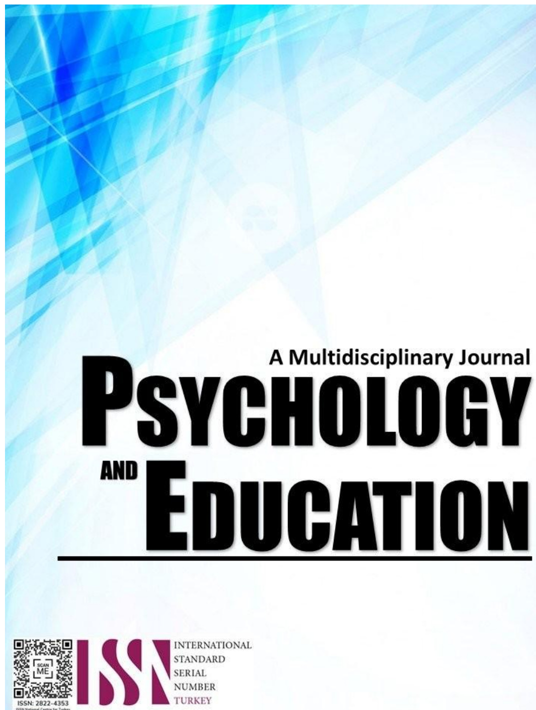
THE EFFECTS OF A FLIPPED CLASSROOM TEACHING METHOD INTEGRATED WITH A COLLABORATIVE LEARNING MODEL ON STUDENTS' LEARNING PERFORMANCE IN GENETICS



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Research Article

The Effects of a Flipped Classroom Teaching Method Integrated with a Collaborative Learning Model on Students' Learning Performance in Genetics

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Abstract

Difficulties in mastering complex Genetics concepts persist among senior high school learners, prompting the need for innovative pedagogical approaches beyond traditional lecture-based instruction. This study investigated the effects of the flipped classroom teaching method integrated with a collaborative learning model on the learning performance of STEM Grade 11 students in Genetics at Notre Dame of Midsayap College. Employing a quasi-experimental design with non-equivalent control and experimental groups, the control group was taught using the traditional deductive method. In contrast, the experimental group received flipped classroom instruction incorporating collaborative activities. Both groups took a pre-test to establish baseline comparability and a post-test to measure learning gains. Results revealed that the flipped classroom, integrated with a collaborative learning model, was rated "very high" in implementation, with teacher guidance, student motivation, and the accessibility of pre-class materials identified as key strengths. Post-test scores of the experimental group (M = 86.40) were significantly higher than those of the control group (M = 78.15), with a larger mean gain (14.60 vs. 5.80) and a large effect size (d = 1.92), indicating substantial improvement in student performance. These findings suggest that the flipped classroom, combined with collaborative learning, is more effective than traditional methods in enhancing academic achievement, fostering active engagement, and developing critical thinking in Genetics. The results further affirm the importance of innovative, student-centered instructional models in advancing Sustainable Development Goal 4 – Quality Education.

Keywords: *flipped classroom, collaborative learning, learning performance, science education, SDG 4*

Introduction

"If we teach today's students as we taught yesterday, we rob them of tomorrow," said John Dewey (1986), emphasizing the urgent need to evolve teaching methods that actively engage learners. In the context of science education, where students must develop higher-order thinking skills to become globally competitive, reliance on lecture-based instruction is no longer sufficient. Learners require opportunities to participate, collaborate, and apply concepts rather than remain passive recipients of information. However, traditional didactic approaches often lead to disengagement and limited retention, underscoring the need for more dynamic and learner-centered strategies.

Global academic assessments reinforce this concern. The Philippine performance in the Programme for International Student Assessment (PISA) in 2018 and 2022 consistently ranked below the global average, revealing persistent gaps in student competencies relative to international standards (Acido & Caballes, 2024). Likewise, results from the 2019 Trends in International Mathematics and Science Study (TIMSS) showed that the Philippines scored 297 in Mathematics and 249 in Science, the lowest among 58 participating countries (Magas, 2023). These findings underscore the crucial need to adopt innovative pedagogies to enhance student outcomes in science learning.

The limitations of traditional lecture-based teaching have also been documented globally. In Sudan, students reported that lectures were the least effective in promoting meaningful learning outcomes (Alaagib et al., 2019). International scholars further argue that instruction must focus on cultivating student learning outcomes rather than simply transmitting content (Samarasekera et al., 2018). In Mainland China, lecture-dominated classrooms were found to impede engagement and discourage critical thinking, demonstrating how passive approaches can limit deeper cognitive processing (Hu et al., 2024; Wang et al., 2024). Similar challenges exist in the Philippines, where traditional instruction is increasingly viewed as misaligned with contemporary learning needs and insufficient in promoting active participation (Cadiz et al., 2024; Edar et al., 2024). Consequently, local researchers have advocated for more innovative and student-centered approaches, including the integration of technology and collaborative learning tools, to enhance instructional effectiveness (Vega, 2024; Bisin & Sumayo, 2024; Gogo, 2024).

One emerging approach that addresses these challenges is the flipped classroom model. By shifting direct instruction outside of classroom hours and devoting in-class sessions to application-based, interactive activities, the flipped classroom transforms learning environments into active and collaborative spaces. Research suggests that this model can enhance engagement and improve learning outcomes; however, its effectiveness varies across contexts, disciplines, and implementations (Wright & Park, 2022). Moreover, the model demands greater student responsibility, requiring self-regulation, preparation, and collaboration (Jung et al., 2022). These considerations underscore the need for further empirical studies, particularly in science education, where the combined use of flipped instruction and collaborative learning remains underexplored.

In alignment with Sustainable Development Goal 4 (Quality Education), this study examines the impact of integrating the flipped classroom teaching method with a collaborative learning model on the learning performance of STEM Grade 11 students at Notre

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Dame of Midsayap College. By examining its effectiveness in teaching Genetics, the study seeks to contribute to a deeper understanding of how innovative instructional strategies can be designed and implemented to enhance academic performance in science and foster meaningful student engagement.

Research Questions

This study aims to investigate the impact of the flipped classroom teaching method, combined with a collaborative learning model, on the learning performance of STEM Grade 11 students in Genetics at Notre Dame of Midsayap College. Specifically, it seeks to answer the following questions:

1. What are the mean pretest scores of students in the control and experimental groups prior to the implementation of the flipped classroom integrated with a collaborative learning model?
2. What are the mean posttest scores of students in the control and experimental groups after the implementation of the flipped classroom integrated with a collaborative learning model?
3. Is there a significant difference between the pretest and posttest mean scores of students in the control and experimental groups?
4. Is there a significant difference between the posttest mean scores of students in the control and experimental groups?
5. Is there a significant difference between the mean gain scores of students in the control and experimental groups?
6. What is the overall effect of the flipped classroom integrated with a collaborative learning model on students' learning performance?

Literature Review

Flipped Classroom

The flipped classroom has emerged as a widely adopted instructional model in response to the limitations of traditional lecture-based teaching. In this approach, direct instruction is delivered outside the classroom through videos, readings, and other digital materials, freeing class time for interactive, application-based activities. A meta-analysis by Strelan et al. (2020) found that flipped learning consistently outperforms traditional instruction, reporting moderate to large effect sizes on learner achievement when active learning strategies are incorporated during class hours. The success of this model is attributed to its shift from passive knowledge reception to active meaning-making, a critical factor in science learning.

According to Wright and Park (2022), the effectiveness of the flipped classroom depends heavily on contextual alignment—namely, the quality of instructional materials, teachers' competence in facilitating in-class engagement, and students' accountability for pre-class preparation. In their study of flipped learning across disciplines, they found that STEM subjects are particularly receptive to the model due to the cognitive demands of problem-solving and concept application.

Beyond higher education, recent studies have shown its applicability in secondary education as well. Lam et al. (2024) found that integrating pre-class multimedia resources in science subjects enhances comprehension, particularly when combined with structured follow-up activities. Similarly, Naing et al. (2023) found that students in flipped classrooms scored higher on assessment tasks than those in traditionally taught classes. However, both studies noted that student success in flipped classrooms requires self-regulation and teacher scaffolding, which are not always present in all learning environments.

Other scholars emphasize the importance of implementation fidelity. Jung et al. (2022) reported that flipped classroom failures stem largely from students' failure to engage with pre-class materials. Holm et al. (2022), in a randomized controlled trial, concluded that pre-class preparation yields learning gains only when in-class time emphasizes interaction, reflection, and collaboration. Across studies, researchers agree that flipping the classroom alone is insufficient unless supported by strategies that engage learners during class time.

Collaborative Learning as the Integrated Strategy

Collaborative learning has long been recognized as a practical pedagogical approach, rooted in social constructivist theories that argue learning is co-constructed through interaction. In recent years, collaborative learning models have been increasingly used to enhance STEM education. A mixed meta-analysis by Yaşar et al. (2024) found that collaborative learning in science education produces small-to-moderate positive effects on academic achievement and engagement when well-structured group roles, interdependence, and assessment mechanisms are in place.

In diverse contexts, collaborative learning has been shown to increase student motivation, critical thinking, and problem-solving abilities. Hu et al. (2024) reported that collaborative science classrooms in China create active learning environments where students explain concepts to one another, correct misconceptions, and co-design solutions. Similarly, Samarasekera et al. (2018) stressed that instruction should not focus solely on content delivery but on the co-construction of knowledge within group settings.

In the study by Alaagib et al. (2019), students perceived lecture-based instruction as less effective because it limited peer support and engagement, reinforcing the need for more interactive models. Local Philippine scholars have echoed this sentiment, emphasizing that traditional methods are misaligned with 21st-century learning needs (Cadiz et al., 2024; Edar et al., 2024). Gogo (2024) and Vega

(2024) advocate the use of collaborative methods, especially when paired with technology, to promote deeper engagement and improve learning outcomes.

Recent literature also highlights the role of socially shared regulation of learning (SSRL) in successful collaboration. According to Järvenoja et al. (2020), effective collaboration requires shared goal-setting, monitoring, and reflective practice. Sulla et al. (2023) note that teacher facilitation and structured group processes can significantly enhance the effectiveness of collaborative learning. These findings suggest that collaborative learning is not merely group work but a guided cognitive process that enhances academic outcomes.

Learning Performance as the Dependent Variable (DV)

Learning performance as a construct encompasses test scores, conceptual understanding, cognitive gains, and the application of knowledge. In the context of declining educational outcomes globally, performance has become a critical focus of instructional research. Cadiz et al. (2024) and Edar et al. (2024) assert that disengagement and passive learning contribute to poor academic performance in secondary science education, particularly when students are expected to recall rather than apply knowledge.

In the Philippines, the 2018 and 2022 PISA results showed that students consistently scored below global standards, raising concerns about the quality of teaching and methodologies (Acido & Caballes, 2024). Similarly, the TIMSS 2019 report placed the country last in both science and mathematics among 58 nations (Magas, 2023). These reports emphasize the need for instructional innovation to improve performance.

Research indicates that flipped classrooms and collaborative learning interventions yield higher post-test scores compared to traditional instruction. Naing et al. (2023) found that flipped students achieved significantly higher scores in science assessments, while Lam et al. (2024) reported notable gains in conceptual understanding and retention. In science-practical contexts, Sanjito and Hyams-Ssekasi (2025) demonstrated that students exposed to active learning models outperformed those in teacher-centered environments in both practical skill assessments and written tests.

Collaborative learning also positively influences performance. Yaşar et al. (2024) found that collaborative structures enhance conceptual depth, while Wright and Park (2022) demonstrated that collaborative discussions facilitate knowledge internalization. These findings imply that performance gains are shaped not only by access to content but also by opportunities to apply, articulate, and reflect on learning.

Integration of Flipped and Collaborative Learning in Science and Genetics

Researchers increasingly argue that flipped learning is most effective when paired with collaborative models. Buhl-Wiggers et al. (2023) noted that students retain more from flipped classrooms when in-class sessions include peer instruction, group problem-solving, and inquiry-based tasks. In their study, students performed significantly better when required to apply pre-class content collaboratively.

The study by Lam et al. (2024) emphasized that science subjects, particularly biology and genetics, require active engagement and conceptual exchange to support understanding of abstract processes. Flipped classrooms provide time for these interactive tasks, while collaborative learning structures ensure students actively participate during class sessions. Naing et al. (2023) similarly found that flipped instruction improves outcomes most when paired with structured group work.

Within genetics education, several quasi-experimental studies provide empirical support for this integration. Abbas et al. (2024) reported that students taught through a flipped-collaborative model performed better on genetics assessments than those receiving lecture-based instruction. Nnorom and Okwutu (2025) found that simulation-based flipped lessons with collaborative discussion significantly increased student interest and achievement in genetics.

These studies suggest that genetics concepts—which often involve abstract models, biological mechanisms, and multi-step reasoning—benefit from a learning environment where students can discuss, visualize, and apply concepts with peers. Collaborative flipped instruction creates this structure.

Local Context and Alignment with SDG 4

In the Philippine context, persistent underperformance in science necessitates the adoption of student-centered pedagogies. OECD (2023) data show that Filipino students perform below proficiency levels in science literacy, reflecting systemic challenges in instruction and curriculum. Traditional, lecture-based models fail to engage learners and discourage higher-order thinking (Cadiz et al., 2024; Edar et al., 2024).

As the Philippine education system aligns with Sustainable Development Goal 4 (Quality Education), reforms in pedagogy are increasingly emphasized. Flipped and collaborative models support SDG 4's aim to promote inclusive, equitable, and quality learning through active participation, digital integration, and learner autonomy. Bisin and Sumayo (2024) stress that integrating technology with student-centered learning approaches enhances access and engagement, especially in secondary science education.

On the other hand, Vega (2024) emphasizes that local schools must shift toward methods that promote thinking, collaboration, and application, especially in STEM subjects. Gogo (2024) further notes that collaborative strategies build confidence, communication, and academic performance among Filipino learners.

Given the limited literature on flipped and collaborative learning specifically in Philippine high school genetics, the present study addresses both a research gap and a pressing educational need.

Methodology

Research Design

This study employed a quasi-experimental design, specifically the non-equivalent control group pre-test–post-test design. Two groups of STEM Grade 11 students were selected: one served as the control group and was taught using the traditional deductive method, while the other served as the experimental group and was taught using a flipped classroom approach integrated with collaborative learning activities. A pre-test was administered to both groups to establish their baseline knowledge, followed by the implementation of their respective instructional methods. After the intervention, both groups took a post-test to measure changes in their academic performance. This design was chosen as it allowed for the comparison of teaching approaches in an actual classroom environment where random assignment was not feasible.

Respondents

The respondents of this study were 60 STEM Grade 11 students from Notre Dame of Midsayap College during the Academic Year 2023–2024. They were divided into two intact groups using a quasi-experimental non-equivalent control group design: 30 students formed the experimental group, which received instruction through a flipped classroom integrated with a collaborative learning model, while another 30 students comprised the control group, which was taught using the traditional deductive method. To measure student performance, a researcher-made achievement test in Genetics was administered, covering core concepts such as Mendelian inheritance, non-Mendelian inheritance patterns, probability in genetics, and problem-solving based on genetic principles. The instrument's validity was established through expert evaluation by specialists in science education. At the same time, its reliability was confirmed through a pilot test with non-participating students, yielding an acceptable Cronbach's alpha coefficient, which indicates the test's internal consistency.

Instrument

The primary instrument used in this study was a 40-item researcher-developed Genetics Achievement Test, designed to assess students' prior knowledge and learning gains before and after the intervention. The test items were distributed across four core competencies aligned with the Grade 11 STEM curriculum: Mendelian inheritance (12 items), non-Mendelian inheritance patterns (10 items), probability in genetics (8 items), and genetics problem-solving (10 items). To establish content validity, the instrument was evaluated by three experts—two licensed Biology educators with graduate degrees in science education and one curriculum specialist in secondary science instruction. They assessed the test based on content relevance, clarity, alignment with learning competencies, and appropriateness for the target learners. The validation yielded an overall Content Validity Index (CVI) of 0.92, indicating excellent content relevance. Minor revisions were made to the phrasing and difficulty level of items based on their feedback. The test was then pilot-tested among 20 Grade 11 STEM students from a different section, not included in the main study. Reliability analysis using Cronbach's alpha yielded a coefficient of 0.87, confirming the instrument's internal consistency and suitability for measuring students' learning performance in Genetics.

Procedure

The study's conduct followed a systematic procedure. First, both groups were given a pre-test to assess their initial knowledge of genetics. Second, the control group was taught using the traditional, lecture-based, deductive method. In contrast, the experimental group was taught using the flipped classroom model, in which students studied video lectures and reading materials before class and engaged in collaborative tasks, discussions, and problem-solving during class time. Third, a post-test was administered to both groups using the same validated instrument. Finally, the scores were tabulated and prepared for statistical analysis to compare the effectiveness of the two instructional methods.

Data Analysis

The data gathered were analyzed using both descriptive and inferential statistics. Descriptive statistics, such as mean and standard deviation, were used to summarize student performance in both the pre-test and post-test. Before conducting inferential analyses, the normality of score distributions for both the control and experimental groups was assessed using the Shapiro–Wilk test, which is appropriate for small to moderate sample sizes. Results indicated that the data did not deviate significantly from normality ($p > 0.05$), thereby justifying the use of parametric tests. Following this verification, paired-samples t-tests were used to determine significant differences between pre- and post-test scores within each group. In contrast, independent-samples t-tests were used to compare post-test scores between the control and experimental groups. Mean gain scores were computed to evaluate improvement, and Cohen's d was calculated to determine the effect size and magnitude of the intervention. All statistical tests were conducted at a 0.05 level of significance.

Ethical Considerations

The study adhered to ethical research standards. Consent was secured from both the students and their parents prior to participation. The participants were assured that their involvement was voluntary, their identities would remain anonymous, and their responses would be kept confidential. Furthermore, the collected data were used solely for academic purposes and reported in aggregate to ensure respondents' privacy.

Results and Discussion

This table displays the baseline performance of both the control and experimental groups, prior to the intervention, using a researcher-developed Genetics Achievement Test.

Table 1. *Descriptive Statistics for Pretest Scores by Group*

Group	*n*	*Mean*	*SD*
Control	30	72.35	5.20
Experimental	30	71.80	5.10

Table 1 shows that the control group (M = 72.35, SD = 5.20) and the experimental group (M = 71.80, SD = 5.10) had nearly equivalent pretest scores, indicating that the groups were comparable before the intervention. This similarity in initial performance strengthens the study's internal validity, as improvements on the posttest can be attributed to the flipped classroom integrated with collaborative learning rather than to baseline differences. This comparability aligns with Buhl-Wiggers et al. (2023), who emphasized the importance of equivalent initial conditions in quasi-experimental designs.

Table 2 presents the posttest performance of both groups after the intervention.

Table 2. *Descriptive Statistics for Posttest Scores by Group*

Group	*n*	*Mean*	*SD*	*Performance Interpretation*
Control	30	78.15	4.25	Satisfactory
Experimental	30	86.40	3.95	Very Satisfactory

The experimental group (M = 86.40, SD = 3.95) outperformed the control group (M = 78.15, SD = 4.25), indicating higher mastery of Genetics concepts after the intervention. The difference suggests that exposure to pre-class materials and collaborative application resulted in better retention and understanding, consistent with Wright and Park (2022) and Vega (2024), who highlight the cognitive advantages of active learning environments over lecture-based teaching.

Table 3. Shows the differences in the mean scores of each group from pretest to posttest.

Table 3. *Within-Group Changes (Paired t-Tests) in Pretest vs. Posttest Scores*

Group	*Test*	*Mean*	*SD*	*t*	*p*	*Interpretation*
Control	Pretest	72.35	5.20			
	Posttest	78.15	4.25	6.42	< .001	Significant
Experimental	Pretest	71.80	5.10			
	Posttest	86.40	3.95	12.85	< .001	

Both groups demonstrated significant improvement from the pretest to the posttest. However, the experimental group demonstrated a much larger increase (mean gain = 14.60) compared to the control group (mean gain = 5.80). This suggests that while traditional instruction contributes to learning, the flipped classroom approach, combined with collaborative learning, promotes a deeper conceptual understanding. This outcome supports the findings of Alaagib et al. (2019) and Samarasekera et al. (2018), who argue that lecture-based approaches limit engagement and knowledge construction.

Table 4 compares the post-intervention performance between the two groups.

Table 4. *Between-Group Difference in Posttest Scores (Independent t-Test)*

Group	*n*	*Mean*	*SD*	*t*	*p*	*Interpretation*
Control	30	78.15	4.25			
Experimental	30	86.40	3.95	8.25	< .001	

There is a statistically significant difference in favor of the experimental group. This confirms that integrating flipped instruction with collaborative learning produces stronger mastery of Genetics concepts than traditional deductive teaching. This aligns with Wang et al. (2024) and Cadiz et al. (2024), who noted that passive instruction limits motivation and retention.

Table 5 presents the improvement in scores from the pretest to the posttest.

Table 5. *Comparison of Mean Gain Scores (Posttest – Pretest)*

Group	*Pretest Mean*	*Posttest Mean*	*Mean Gain*	*t*	*p*	*Interpretation*
Control	72.35	78.15	5.80			
Experimental	71.80	86.40	14.60	7.95	< .001	

The experimental group's mean gain (14.60) was significantly greater than that of the control group (5.80), reinforcing the idea that the flipped classroom accelerates learning. This supports the claims of Bisin and Sumayo (2024) that innovative teaching methodologies produce transformative learning gains rather than incremental ones.

Table 6 shows the magnitude of the intervention effect using Cohen's d.

Table 6. *Effect Size for Between-Group Difference in Posttest Scores*

Comparison	*Mean Difference*	*SD (Pooled)*	*Cohen's d*	*Effect Interpretation*
Experimental vs. Control (Posttest)	8.25	4.12	1.92	Large

A Cohen's d of 1.92 indicates a considerable effect, demonstrating that the intervention had a powerful impact on student achievement in Genetics. This confirms that the flipped classroom with collaborative learning is not just statistically significant but educationally meaningful.

Table 7 evaluates the intervention's effectiveness based on student perceptions.

Table 7. *Implementation of the Flipped Classroom Integrated with a Collaborative Learning Model (Per-Item)*

Item Indicator	*Mean*	*SD*	*Interpretation*
1. Accessibility of learning materials before class	4.35	0.58	Very High
2. Student preparation prior to classroom sessions	4.10	0.61	High
3. Collaboration with peers during in-class activities	4.25	0.55	Very High
4. Engagement in problem-solving activities	4.30	0.50	Very High
5. Teacher guidance and feedback during discussions	4.45	0.52	Very High
6. Improvement of critical thinking skills	4.20	0.63	High
7. Motivation and interest in learning Genetics	4.40	0.54	Very High
Overall Mean	4.29	0.56	Very High

The highest-rated indicator was teacher guidance (M = 4.45), emphasizing the role of facilitation in student-centered instruction (Hu et al., 2024). The lowest, student preparation (M = 4.10), reflects common challenges in flipped settings that require self-regulation (Jung et al., 2022). Despite this, the overall "Very High" rating aligns with the significant performance gains.

Conclusions

This study investigated the effects of the flipped classroom teaching method integrated with a collaborative learning model on the learning performance of STEM Grade 11 students in Genetics at Notre Dame of Midsayap College. The findings consistently demonstrated that the intervention was significantly more effective than traditional deductive teaching.

Both the control and experimental groups showed improvement from pretest to posttest; however, the experimental group achieved notably higher scores, larger mean gains, and a huge effect size (Cohen's d = 1.92). The mean posttest score of 86.40 in the experimental group, compared to 78.15 in the control group, confirms that students benefited from accessing learning materials before class and applying concepts through peer collaboration during class sessions. The significant gain of 14.60 points in the experimental group, compared with 5.80 in the control group, further highlights the intervention's accelerated learning impact.

Implementation fidelity was rated "Very High" (M = 4.29), indicating that students perceived teacher guidance, peer collaboration, engagement in problem-solving, and access to pre-class resources positively. Although student preparation prior to class received a slightly lower—but still high—rating, the overall evaluation indicated that the instructional approach was well executed and well received.

The results affirm constructivist learning theory, which emphasizes active engagement, interaction, and knowledge construction, and further support previous research advocating for student-centered, technology-supported pedagogies in science education. In light of the Philippines' persistent challenges in international assessments such as PISA and TIMSS, this study provides compelling evidence that the flipped classroom-collaborative learning approach can be a viable means of improving science achievement in senior high school.

The study concludes that integrating flipped instruction with collaborative learning is a powerful and transformative strategy in teaching Genetics. It enhances academic performance, promotes engagement, strengthens critical thinking, and supports Sustainable Development Goal 4 (Quality Education) by advancing inclusive and effective learning practices. The findings underscore the urgent need to transition from passive, lecture-based instruction to innovative, student-centered methodologies in Philippine science education.

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