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The Assessment of Collaborative Learning Strategy and Its Effect on Student's Achievement Score in Biology

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ABSTRACT

This study assessed the extent of utilization of collaborative learning strategies and their relationship with students' achievement scores in Biology. A quantitative, quasi-experimental one-group pretest–posttest design was employed involving 71 high school students selected through convenience sampling at Mitchell High School, Colorado Springs, Colorado, USA. Data were collected using Biology achievement tests and a collaborative learning self-assessment checklist and analyzed through descriptive statistics, paired-samples t-tests, analysis of variance, and Pearson correlation. Findings revealed a significant increase in mean achievement scores from 10.04 to 21.88 ($p < .001$). Collaborative learning was highly utilized ($M = 3.02$), with quality of interaction and communication receiving the highest rating. Utilization differed significantly according to grade level but not according to age or sex. A significant negative correlation between collaborative learning utilization and post-test achievement was identified ($r = -0.580$, $p < .001$), although its interpretation requires verification of variable coding. The study concludes that structured collaborative instruction was accompanied by substantial improvements in Biology achievement. Strengthening active participation, individual accountability, teacher professional development, and structured group activities is recommended. However, convenience sampling, unequal grade-level representation, and the absence of a comparison group limit generalizability and causal interpretation. The study provides an empirical foundation for developing a collaborative learning enhancement framework that informs instructional planning, curriculum improvement, and institutional decision-making. Its findings support the advancement of evidence-based, inclusive, and sustainable practices in secondary Biology education.

Keywords: *Academic Achievement, Biology Education, Collaborative Learning, Individual Accountability, Positive Interdependence, Quasi-Experimental Design, Student Engagement*

1. INTRODUCTION

Collaborative learning is a student-centered instructional strategy that promotes active engagement, peer interaction, shared responsibility, and higher-order thinking skills in science education (Chen & Chen, 2025; Gillies, 2023; Lee & Kang, 2024). Its integration with digital technologies and inquiry-based instruction enhances interactive learning environments (Bilici & Yilmaz, 2024; Chen & Chen, 2025). Evidence indicates that cooperative learning improves academic achievement and self-concept (Agwu & Nmadu, 2023), Biology performance (Driessen et al., 2024; Kebede et al., 2025), and student engagement (Gillies, 2023). Contemporary education emphasizes inquiry-based and problem-based collaborative approaches (Chen & Chen, 2025; Gillies, 2023), technology-enhanced interaction (Bilici & Yilmaz, 2024; Chen & Chen, 2025), and cognitive, social, and communication competencies (Lee & Kang, 2024; Zhou & Colomer, 2024). These approaches strengthen academic achievement (Agwu & Nmadu, 2023; Cochon Drouet et al., 2023), self-concept (Agwu & Nmadu, 2023), motivation (Cochon Drouet et al., 2023; Soriano-Sánchez et al., 2025), and knowledge construction (Chen & Chen, 2025). In Biology, collaborative instruction improves conceptual understanding and retention (Driessen et al., 2024; Kebede et al., 2025), while digital storytelling enhances achievement and critical thinking (Bilici & Yilmaz, 2024). Driessen et al. (2024) and Yaşar et al. (2024) demonstrated the positive effects of group learning on academic performance, including metacognitive development (Durak & Arslantaş, 2026) and engagement (Gillies, 2023; Kebede et al., 2024). Similarly, Cochon Drouet et al. (2023) emphasized academic motivation, while Kebede et al. (2024) highlighted peer interaction. Gillies (2023) supported inquiry-based instruction alongside technology-enhanced collaboration (Bilici & Yilmaz, 2024). Driessen et al. (2024) and Yaşar et al. (2024) further reinforced the effectiveness of structured group learning. Accordingly, this study examines the utilization of collaborative learning strategies and their effect on students' Biology achievement at Mitchell High School in Colorado Springs, Colorado, United States.

Research Problem

Despite its benefits, collaborative learning faces challenges arising from teacher-centered instruction (Kebede et al., 2025), educational inequities (Monteiro et al., 2024), unequal participation, insufficient guidance (Gillies, 2023; Monteiro et al., 2024), and organizational constraints (Kebede et al., 2024). International assessments (von Davier et al., 2024) reveal persistent achievement disparities (Organisation for Economic Co-operation and Development [OECD], 2023; von Davier et al., 2024) and difficulties in applying scientific knowledge and higher-order thinking skills (von Davier et al., 2024). Although the Next Generation Science Standards promote equitable, inquiry-based instruction (NGSS Lead States, 2013) and collaborative scientific investigation (NGSS Lead States, 2013), implementation challenges remain. At Mitchell High School, declining science achievement, linguistic diversity, and students' external work commitments present instructional challenges. Effective collaboration requires appropriate group structures and teacher facilitation (Gillies, 2023; Kebede et al., 2025), while unequal participation and communication difficulties may hinder learning (Monteiro et al., 2024). Effective communication enhances scientific understanding (Chen & Chen, 2025; Gillies, 2023), whereas poor coordination and unequal participation undermine collaboration (Monteiro et al., 2024). Structured cooperative learning produces better academic outcomes (Yaşar et al., 2024), although classroom management difficulties (Gillies, 2023; Kebede et al., 2024) and insufficient teacher preparation remain barriers (Kebede et al., 2025). Limited research examines measurable achievement scores in secondary Biology (Kebede et al., 2025), particularly regarding group dynamics and implementation factors (Driessen et al., 2024). Further investigation is therefore necessary to establish the relationship between collaborative learning utilization and subject-specific achievement (Driessen et al., 2024; Kebede et al., 2024, 2025).

This study addresses these gaps through quantitative analysis of collaborative learning practices and Biology achievement scores.

Assumptions of the Study

The study assumes that structured collaborative learning enhances Biology achievement through active participation, positive interdependence, individual accountability, and effective communication. These practices promote cognitive and social competencies (Gillies, 2023; Lee & Kang, 2024) and meaningful knowledge construction (Chen & Chen, 2025; Kebede et al., 2024). Effective collaboration requires clearly defined roles and responsibilities (Gillies, 2023), appropriate group sizes (Driessen et al., 2024), and structured cooperative interaction (Gillies, 2023; Yaşar et al., 2024; Zhou & Colomer, 2024). The study utilizes pre-test and post-test scores to measure achievement, with age, sex, and grade level serving as demographic grouping variables. The null hypotheses assume no significant differences in post-test scores, pre-test and post-test performance, or collaborative learning utilization when grouped according to demographic profile, and no significant relationship between collaborative learning utilization and post-test achievement. The alternative hypotheses propose significant differences or relationships. The investigation is limited to quantitative measures of collaborative learning and Biology achievement among selected high school students, excluding other potential influences such as teacher experience, socioeconomic status, and individual learning differences.

Objectives of the Study

This study aims to assess the utilization of collaborative learning strategies and their effect on students' achievement scores in Biology. Specifically, it seeks to identify respondents' demographic profiles in terms of age, sex, and grade level; determine their mean pre-test scores and mean post-test scores according to demographic profile; and assess collaborative learning utilization in terms of active participation, positive interdependence, individual accountability, and interaction and communication. It further aims to determine whether significant differences exist between pre-test and post-test achievement scores, examine collaborative learning utilization according to demographic profile, and establish whether a significant relationship exists between collaborative learning utilization and post-test achievement scores. Based on the findings, the study seeks to develop a research-based instructional improvement plan or intervention.

Conceptual and Theoretical Framework

The study is anchored in Social Constructivism Theory, Cooperative Learning Theory, Cognitive Learning Theory, and Collaborative Learning Theory. Vygotsky's Social Constructivism Theory emphasizes knowledge construction through social interaction, scaffolding, and the Zone of Proximal Development, supporting conceptual understanding and academic achievement (Chen & Chen, 2025; Vygotsky, 1978). Johnson and Johnson's Cooperative Learning Theory highlights positive interdependence, individual accountability, promotive interaction, interpersonal skills, and group processing as essential components of effective collaboration (Gillies, 2023; Johnson & Johnson, 2009; Yaşar et al., 2024). Piaget's Cognitive Learning Theory emphasizes active knowledge construction, cognitive engagement, and problem-solving, which contribute to higher-order thinking and academic achievement (Driessen et al., 2024; Piaget, 1952). Collaborative Learning Theory similarly promotes shared responsibility, peer interaction, and meaningful learning (Dillenbourg, 1999; Gillies, 2023). These theories support active participation, positive interdependence, individual accountability, and effective communication (Johnson et al., 2014; Yaşar et al., 2024; Zhou & Colomer, 2024), which strengthen cognitive engagement and achievement (Bilici & Yilmaz, 2024; Driessen et al., 2024). However, structured implementation remains essential to prevent unequal participation and disengagement (Gillies,

2023; Monteiro et al., 2024). The conceptual framework follows the Input–Process–Output (IPO) model. Inputs include demographic characteristics, pre-test scores, and collaborative learning indicators. The process involves collaborative instruction, achievement assessments, and statistical analysis. Outputs include achievement differences, relationships between variables, and a proposed instructional improvement plan. Collaborative learning utilization constitutes the independent variable, Biology achievement scores represent the dependent variable, and demographic characteristics serve as grouping and proposed moderating variables.

Sustainable Development Goal and Multidisciplinary Sustainability Relevance

The study aligns with SDG 4 – Quality Education, particularly Target 4.1, which promotes equitable secondary education and effective learning outcomes (United Nations General Assembly, 2015). By assessing collaborative learning strategies, the research supports inclusive, learner-centered, and evidence-based Biology instruction. The study contributes to educational sustainability by promoting academic achievement, scientific literacy, critical thinking, communication, teamwork, and lifelong learning competencies (Chen & Chen, 2025; UNESCO, 2023). It also supports institutional sustainability by providing empirical evidence for teacher professional development, curriculum improvement, and instructional decision-making. Through structured collaborative learning, the research promotes inclusive and sustainable educational practices that strengthen students' academic performance and support the continuous improvement of secondary science education.

2. METHODOLOGY

Research Design

The study employed a quantitative, quasi-experimental one-group pretest–posttest design to determine the effect of collaborative learning strategies on students' Biology achievement. A pre-test was administered to establish baseline knowledge, followed by structured collaborative activities, including group discussions, peer teaching, and cooperative tasks. A post-test was subsequently administered to measure learning gains. The design involved manipulating the independent variable without random assignment, allowing the intervention to be evaluated within an actual classroom setting (Creswell & Creswell, 2023).

Research Locale or Study Setting

The study was conducted at Mitchell High School, a public secondary school in Colorado Springs, Colorado, USA. The school serves a diverse student population and incorporates collaborative and team-based instructional strategies in science education. Its structured classroom environment, accessibility, and availability of participants provided an appropriate setting for examining collaborative learning and Biology achievement.

Participants or Data Sources

The study involved 71 high school students enrolled in science classes at Mitchell High School, where collaborative learning strategies were implemented. Convenience sampling was employed based on participant accessibility, time constraints, and research feasibility. Intact groups were utilized without random assignment. Respondents were classified according to age, sex, and grade level. Although convenience sampling limited the generalizability of the findings, it facilitated the investigation within an actual classroom setting (Creswell & Creswell, 2023).

Research Instruments or Materials

The study utilized a standardized Biology pre-test and post-test supplemented by a collaborative learning self-assessment checklist. The achievement test consisted of 27 multiple-choice and three open-ended questions aligned with Biology curriculum standards, with a maximum score

of 100 points administered through Schoology. The checklist assessed active participation in group activities, positive interdependence, individual accountability, and quality of interaction and communication using a four-point rating scale ranging from 1 (Beginning) to 4 (Exemplary). To establish content validity, at least three experts in Biology education and educational research evaluated the instruments for relevance, clarity, and alignment with the research objectives. Revisions were made based on expert feedback, and pilot testing was conducted to improve instrument clarity and reliability.

Data Gathering Procedure

Prior to data collection, permission was obtained from the school administration, and participants were informed about the study's purpose and procedures. The research instruments were prepared, validated, and pilot-tested. A pre-test was administered to 71 students to establish their baseline knowledge in Biology, followed by structured collaborative learning activities. During the intervention, students utilized a collaborative learning checklist to assess their engagement. A post-test was subsequently administered to measure changes in academic achievement. The collected responses were checked for completeness, coded, recorded, and organized in a spreadsheet for statistical analysis.

Data Analysis

The collected data underwent coding, entry, and cleaning to ensure accuracy and completeness. Descriptive statistics, including frequency counts, percentages, mean, and standard deviation, were used to summarize respondents' demographic profiles, collaborative learning utilization, and achievement scores. A paired-samples t-test was employed to determine significant differences between pre-test and post-test scores. Where applicable, an independent-samples t-test and one-way analysis of variance (ANOVA) were used to examine differences according to demographic characteristics, while correlation analysis was identified as an additional inferential procedure. Statistical analysis was conducted using appropriate statistical software, such as SPSS, at a significance level of 0.05 (Field, 2024). The null hypothesis was rejected when the p-value was less than or equal to 0.05 and was not rejected when the p-value exceeded 0.05.

Ethical Consideration

The study adhered to institutional guidelines and established ethical principles to protect participants' rights, dignity, and welfare. Formal permission was obtained from the school administration, and informed consent was secured before participation. Respondents were informed of the study's purpose, procedures, and duration, and their participation was voluntary, with the right to withdraw without penalty. Confidentiality and anonymity were maintained through coded identifiers and password-protected digital files accessible only to the researcher and authorized academic personnel. Data retention and disposal followed institutional policies. Measures were implemented to prevent physical, psychological, and academic harm. Artificial intelligence (AI) use was limited to language editing and organization, while data analysis and interpretation remained the researcher's responsibility.

3. RESULTS AND DISCUSSION

3.1 Assessment of Collaborative Learning and Biology Achievement

3.1.1 Demographic Profile of the Respondents

Among the 71 respondents, 49.3% were aged 15 years and below, 35.2% were aged 16–17 years, and 15.5% were aged 18–19 years. Males constituted 50.7% of the respondents, while females accounted for 49.3%. Most respondents were in Grade 9 (78.9%), followed by Grade 11 (15.5%), Grade 10 (4.2%), and Grade 12 (1.4%). The nearly balanced distribution according to sex provided

a basis for comparing collaborative learning experiences between male and female students. However, the predominance of Grade 9 students indicates that the findings primarily reflect the learning experiences of younger secondary school students.

3.1.2 Pre-test Achievement Scores in Biology

The respondents obtained a mean pre-test score of 10.04 with a standard deviation of 2.258, indicating moderate prior knowledge of Biology concepts and relatively similar baseline performance. The findings suggest that students possessed foundational knowledge but had considerable room for improvement. Cognitive Learning Theory explains that meaningful learning occurs when students connect new information with existing knowledge through active engagement, discussion, and collaborative problem-solving (National Research Council, 2000; Piaget, 1952).

3.1.3 Post-test Achievement Scores in Biology

Following the implementation of collaborative learning strategies, respondents obtained a mean post-test score of 21.88 with a standard deviation of 3.653. The increase from the pre-test mean of 10.04 indicates substantial improvement in Biology achievement. The improvement supports the findings of Driessen et al. (2024), Kebede et al. (2025), and Yaşar et al. (2024), who emphasized the effectiveness of collaborative learning in improving academic achievement. Similarly, Bilici and Yilmaz (2024) highlighted its contribution to conceptual understanding. Driessen et al. (2024) reported improved Biology performance through group work, while Bilici and Yilmaz (2024) emphasized the academic benefits of collaborative instruction. These findings support Social Constructivism Theory and Cognitive Learning Theory, which emphasize social interaction and active knowledge construction (Piaget, 1952; Vygotsky, 1978).

3.1.4 Extent of Utilization of Collaborative Learning Strategies

Collaborative learning strategies were highly utilized, with a grand mean of 3.02 (SD = 0.578). Quality of interaction and communication received the highest rating (M = 3.10, SD = 0.759), followed by positive interdependence (M = 3.06, SD = 0.791), individual accountability (M = 2.99, SD = 0.707), and active participation in group activities (M = 2.93, SD = 0.816). The findings support Cooperative Learning Theory, which emphasizes meaningful interaction, shared responsibility, and active participation (Johnson & Johnson, 2009). Gillies (2023) highlighted the importance of productive classroom discourse, while Zhou and Colomer (2024) emphasized interaction, accountability, and cooperation. Effective collaborative learning incorporates these essential components (Gillies, 2023; Yaşar et al., 2024; Zhou & Colomer, 2024). Similarly, Kebede et al. (2024) emphasized the contribution of communication and interaction to student engagement and learning outcomes.

3.2 Significant Differences in Biology Achievement and Collaborative Learning Utilization

3.2.1 Significant Difference Between Pre-test and Post-test Achievement Scores

The paired-samples t-test revealed a significant difference between pre-test and post-test scores, with a mean difference of −11.835, a reported t-value of 25.303, 70 degrees of freedom, and p = .000. Significant improvements were observed among males (t = −16.556, p = .000) and females (t = −19.678, p = .000), as well as respondents aged 15 years and below (t = −16.699, p = .000), 16–17 years (t = −14.460, p = .000), and 18–19 years (t = −13.553, p = .000). Significant gains were also recorded among Grade 9 (t = −22.026, p = .000), Grade 10 (t = −10.583, p = .009), and

Grade 11 students (t = −10.864, p = .000). Grade 12 was excluded from inferential analysis because it had only one respondent. The null hypothesis was rejected for the groups with statistically significant results. The findings indicate substantial learning gains following collaborative instruction, consistent with Driessen et al. (2024), Kebede et al. (2025), and Yaşar et al. (2024), who emphasized the academic benefits of collaborative learning. Social Constructivism Theory and Cognitive Learning Theory further explain these improvements through peer interaction, shared experiences, critical thinking, and active knowledge construction (Piaget, 1952; Vygotsky, 1978).

3.2.2 Differences in Collaborative Learning Utilization According to Sex

The ANOVA results revealed no significant differences according to sex in active participation (F = 1.058, p = .307), positive interdependence (F = 0.347, p = .558), individual accountability (F = 0.027, p = .870), and quality of interaction and communication (F = 0.204, p = .653). Overall collaborative learning utilization was likewise not significantly different (F = 0.436, p = .511). The findings suggest that male and female students experienced collaborative learning similarly, supporting its inclusive nature. Zhou and Colomer (2024) emphasized that collaborative learning promotes equitable participation and engagement across diverse learning contexts. These findings further support equal opportunities for participation regardless of sex (Kebede et al., 2025; Monteiro et al., 2024).

3.2.3 Differences in Collaborative Learning Utilization According to Age

No significant differences were observed according to age in active participation (F = 0.197, p = .822), positive interdependence (F = 2.309, p = .107), individual accountability (F = 0.371, p = .691), and quality of interaction and communication (F = 1.541, p = .222). Overall utilization was also not significantly different (F = 1.479, p = .235). The findings indicate that students across different age groups experienced comparable levels of collaborative learning. This supports Lee and Kang (2024), who emphasized that collaborative learning environments provide beneficial learning opportunities across diverse learner groups.

3.2.4 Differences in Collaborative Learning Utilization According to Grade Level

Significant differences were observed according to grade level in positive interdependence (F = 3.225, p = .028), quality of interaction and communication (F = 4.453, p = .007), and overall collaborative learning utilization (F = 4.733, p = .005). However, active participation (F = 2.357, p = .080) and individual accountability (F = 1.752, p = .165) showed no significant differences. The findings suggest that grade level may influence students' cooperation and communication during collaborative activities. Gillies (2023) emphasized that classroom structure, student maturity, and group dynamics influence collaborative learning effectiveness. Differences in developmental maturity and prior learning experiences may explain variations across grade levels.

3.3 Relationship Between Collaborative Learning Strategies and Biology Achievement

Pearson correlation analysis revealed significant negative relationships between post-test achievement scores and active participation (r = −0.410, p = .000), positive interdependence (r = −0.556, p = .000), individual accountability (r = −0.403, p = .000), and quality of interaction and communication (r = −0.373, p = .001). Overall collaborative learning utilization demonstrated the strongest relationship with post-test achievement (r = −0.580, p = .000). Consequently, the null

hypothesis of no significant relationship was rejected. The findings establish a significant association between collaborative learning utilization and Biology achievement. The original discussion attributed the negative coefficients to the coding direction of the variables. Gillies (2023) emphasized the contribution of collaborative engagement to academic outcomes, while Chen and Chen (2025) highlighted interaction and knowledge construction. The significant associations also relate to the findings of Driessen et al. (2024) and Kebede et al. (2024, 2025), who emphasized the academic benefits of collaborative engagement. These findings support the relevance of Social Constructivism Theory and Cooperative Learning Theory in explaining collaborative learning processes (Johnson & Johnson, 2009; Vygotsky, 1978), although the direction of the observed relationships requires verification.

3.4 Synthesis of Findings and Theoretical Implications

The findings revealed high collaborative learning utilization, significant improvements in Biology achievement, and significant relationships between collaborative learning indicators and post-test performance. Students also demonstrated engagement, communication, and shared responsibility during collaborative activities. Gillies (2023) and Zhou and Colomer (2024) emphasized that collaborative environments promote interaction and shared responsibility, while Chen and Chen (2025), Kebede et al. (2024), and Lee and Kang (2024) highlighted participation, communication, and engagement. Similarly, Cochon Drouet et al. (2023) and Lee and Kang (2024) explained the contribution of group interaction to cognitive and social development. Driessen et al. (2024) and Kebede et al. (2025) associated collaborative learning with improved academic performance through peer interaction and knowledge construction. The observed learning gains are consistent with Driessen et al. (2024) and Yaşar et al. (2024), while Gillies (2023) and Kebede et al. (2024) emphasized engagement and participation. Likewise, Chen and Chen (2025), Lee and Kang (2024), and Zhou and Colomer (2024) supported the development of communication and active learning. Collaborative environments also contribute to improved educational and organizational outcomes (OECD, 2025; UNESCO, 2024). The findings relate to the academic benefits identified by Driessen et al. (2024) and Kebede et al. (2025), the collaborative engagement emphasized by Gillies (2023) and Cochon Drouet et al. (2023), and the communication competencies highlighted by Chen and Chen (2025), Kebede et al. (2024), and Lee and Kang (2024). Furthermore, OECD (2025) and UNESCO (2024) reinforced the importance of collaborative learning environments in improving student outcomes.

3.5 Challenges Affecting the Study

The researcher identified limitations involving time constraints, sample size, variability in student participation, and declining institutional science assessment performance. The unequal distribution of respondents across grade levels also limited statistical comparisons, particularly for Grade 12. These challenges may affect the generalizability of the findings and highlight the importance of strengthening classroom collaboration, equitable participation, and instructional implementation. Continuous improvement of collaborative learning practices is necessary to address diverse student needs and support meaningful Biology learning.

3.6 Practical and Policy Implications

The findings demonstrated high utilization of collaborative learning strategies and significant improvements in students' Biology achievement following the intervention. These results provide a basis for strengthening collaborative instructional practices and developing research-informed

educational interventions. Teachers and administrators may utilize the findings to improve instructional strategies, professional development, curriculum planning, and student engagement. Supportive and collaborative educational environments contribute to sustainable institutional improvement (OECD, 2025; UNESCO, 2024). Furthermore, evidence-based decision-making supports effective educational reforms and institutional policies (OECD, 2023).

3.7 Alignment with National and Global Development Priorities

The findings revealed significant learning gains following collaborative instruction, high levels of collaborative learning utilization, and significant associations between collaborative learning indicators and Biology achievement. These findings support Sustainable Development Goal 4 – Quality Education by promoting inclusive, equitable, and evidence-based instruction (United Nations General Assembly, 2015). The study also aligns with AmBisyon Natin 2040 and the Philippine Development Plan (PDP) 2023–2028 through its emphasis on educational quality, human capital development, critical thinking, communication, teamwork, and lifelong learning (National Economic and Development Authority [NEDA], 2016, 2023). Integrating collaborative learning into Biology instruction may contribute to educational sustainability, institutional improvement, and the development of competencies necessary for academic and professional success.

4. CONCLUSIONS AND RECOMMENDATIONS

The study examined the utilization of collaborative learning strategies and their relationship with Biology achievement among 71 students at Mitchell High School in Colorado Springs, Colorado, USA. The findings revealed that collaborative learning was highly utilized, with quality of interaction and communication receiving the highest rating and active participation receiving the lowest. Students demonstrated significant improvement in achievement scores following collaborative instruction across sex, age, and grade-level groups with sufficient respondents. Collaborative learning utilization did not differ significantly according to age and sex, although significant grade-level differences were observed in positive interdependence and quality of interaction and communication. Furthermore, collaborative learning utilization was significantly associated with post-test achievement, although inconsistencies between the reported negative correlation coefficients and their positive interpretation require verification. Collectively, the findings highlight the potential instructional value of structured collaborative learning in Biology and provide an empirical basis for developing an instructional enhancement framework within the educational setting examined.

Biology teachers should strengthen structured collaborative learning activities, particularly active participation and individual accountability, while maintaining effective communication and positive interdependence. Teachers should establish clear group responsibilities, encourage equitable participation, and regularly assess individual and group performance. School administrators should provide professional development and mentoring opportunities to enhance teachers' competencies in collaborative and student-centered instruction. Curriculum developers should integrate structured collaborative activities into Biology lessons while considering students' developmental characteristics and grade-level differences. Educational leaders should consider implementing the proposed RB's Collaborative Learning Enhancement Framework for Biology Achievement, emphasizing assessment of current practices, strategic planning, capacity development, monitoring, and continuous improvement. Regular achievement assessments and collaborative learning evaluations should guide instructional adjustments and evidence-based decision-making. Future researchers should replicate the

study across different educational settings, examine additional factors influencing Biology achievement, and employ alternative research designs to evaluate the effectiveness and sustainability of collaborative learning practices.

The study was limited to 71 students selected through convenience sampling at a single public high school, with Grade 9 students comprising the majority of respondents. The one-group pretest–posttest design and absence of random assignment restricted causal interpretation. Time constraints, unequal grade-level representation, and variability in student participation further limited the generalizability of the findings. The quantitative approach excluded qualitative insights and other potential influences, including teacher experience, socioeconomic status, and individual learning differences. Future studies may address these limitations through larger and more diverse samples, comparison groups, mixed-methods approaches, longitudinal assessments, and the inclusion of additional variables affecting Biology achievement.

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