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The Impact of Peer Collaboration on Grade IX Students' Science Achievement

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ABSTRACT: This study examined how peer collaboration affects Grade IX students' science achievement and their views on collaborative learning. Using a quasi-experimental design with 27 students each in an experimental group (EG) and a control group (CG), researchers conducted pre- and post-tests along with surveys and interviews. While pre-test scores showed no significant difference between groups, post-test results revealed that the EG significantly outperformed the CG, suggesting peer collaboration boosts science learning. Students reported positive experiences, especially with pair work, citing easier communication and knowledge sharing. The study supports Vygotsky's social constructivist theory and highlights the importance of teacher guidance. It recommends integrating peer collaboration into science education and suggests further research on its long-term impact and broader application.

Keywords: peer collaboration, science achievement, Grade IX, quasi-experimental study, collaborative learning, student perceptions

Introduction

Science is being considered by many as an abstract subject with numerous theories and concepts that are confusing (Kraus et al., 2022). And the use of the lecture or traditional method leads to the creation of learning gaps, due to which many of the students show little to no interest in learning science. This, as per the observation in the field, leads many students to blindly agree with what others respond in the class, which is an anchoring bias: a tendency to outwardly express comprehension of material even when facing internal struggles.

This observation prompted the researchers to delve deeper into the underlying reasons behind this behavior. It was discovered that factors such as fear of judgment from teachers and peers, along with reluctance to admit lack of understanding, significantly contribute to this phenomenon. However, it was found that students seek assistance from their peers during free time to clarify doubts or misconceptions. During information peer discussion, students were seen enjoying the process with smiles and laughter, which we believe may be due to

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a more comfortable learning environment. When one is exposed to enjoyment and fun, there will be more dedication to whatever they are doing, and therefore could promote joyful learning promoting deeper understanding of the subject matter (Jørgensen et al., 2024).

A peer guided learning, if in an informal setting, can be that fun, and insightful, a proper structured peer learning could enhance the process of peer learning. This led to the creation of structured peer learning model called TPGA, which is a structured peer collaboration method. TPGA is a four-step learning model which includes Teacher's input, Peer discussion, Group collaborative discussion and Assessment for individuals. According to Chan et al. (2023) during peer discussion, the one who receives the help understand better than during teacher led session.

Furthermore, the researcher was intrigued by the reciprocal nature of peer collaboration-the notion that students who explain concepts to their peers also benefit by reinforcing their own understanding (Matuk & Linn, 2018). Building upon existing literature, there is a growing interest in exploring how structured peer collaboration could potentially enhance academic performance in science among Grade IX students (Pulgar et al., 2020). While prior studies have emphasized the positive impact of peer assistance on academic achievements (Brouwer & Engels, 2021; Altermatt, 2017), the specific implications for Grade IX science education remain relatively underexplored.

Motivated by a desire to contribute meaningful insights to educational practices, the researcher aims to investigate the effectiveness of peer collaboration in improving science performance at this critical stage of secondary education. The primary aim of this study is to illuminate the role of peer interaction in overcoming learning barriers and cultivating a supportive academic environment. Ultimately, the researcher seeks to provide evidence-based recommendations that can inform educators and policymakers about the potential benefits of integrating peer collaboration strategies to enhance science education outcomes for Grade IX students. By understanding and harnessing the power of peer learning dynamics, educators can empower students to navigate challenges and develop a deeper appreciation for scientific concepts during their formative years.

Aims of the Study

This study aims to examine the impact of structured group activities on science performance among Grade IX students.

Situation Analysis

Tangmachu Central School is located far towards the extreme east of the capital city, and its student body predominantly consists of children from farming backgrounds. At home, English is rarely spoken or used in conversation, resulting in significant challenges for students in understanding and comprehending the language. This language barrier poses a substantial obstacle, particularly in the context of science education, where concepts and terminology are primarily presented in English.

Due to these linguistic challenges, many students at Tangmachu Central School resort to rote learning as their primary method of preparing for examinations. Rote learning involves memorization of information without genuine comprehension, leading to surface-level understanding and hindering the development of critical thinking skills. Consequently, students struggle to apply scientific principles in practical contexts or answer questions that require a deeper understanding of the subject matter.

Despite many students failing to understand the concept, there are some students who are able to grasp the concept and many times, it has been observed that students seek help from them to clarify their doubts. This in a simple way is a form of peer collaboration. Prior studies have proved the significance of peer collaboration in enhancing academic performance (Nazeef et al., 2024), however, the situation in the context is a little different for students tends to use their local language in explaining the concept to their friends. Therefore this, study aims to investigate the effectiveness of peer collaboration to bring about improvement in science performance.

Literature Review

Nature of Science Education

Science holds immense importance in modern society as it provides a systematic approach to understanding the natural world and solving complex problems. Belluigi and Cundill (2015) assert that through scientific inquiry, students develop critical thinking skills, curiosity, and a deeper appreciation for the world around them. Science education fosters scientific literacy, empowering individuals to make informed decisions about health, technology, and environmental issues. Furthermore, science plays a pivotal role in driving innovation and technological advancements, contributing to economic growth and societal progress.

However, studying science can be challenging for students due to its abstract and conceptual nature. Many scientific concepts require abstract thinking and visualization skills beyond everyday experiences, which can pose difficulties for learners (DeSutter & Stieff, 2017). Additionally, Ardasheva and Tretter (2015) mentioned that mastering scientific vocabulary and understanding complex theories can be daunting, especially for students with limited exposure to scientific language and academic resources. Therefore, addressing these challenges requires tailored instructional strategies that promote active learning, inquiry-based approaches, and practical applications of scientific principles, which can be possible through peer collaboration (Fakoya et al., 2023).

Rote Learning versus Conceptual Understanding

In science education, the prevalence of rote learning, characterized by memorization of facts and procedures without true comprehension, poses a significant challenge to meaningful learning outcomes. Li and Cutting (2011) stated that rote learning often leads students to focus on memorizing isolated information rather than understanding the underlying principles and connections within scientific concepts. This approach can limit students' ability to apply their knowledge to real-world situations or adapt to novel problems, as they lack a deep understanding of the subject matter. Moreover, relying solely on rote learning can inhibit critical thinking skills and creativity, which are essential for scientific inquiry and problem-solving.

On the other hand, emphasizing conceptual understanding in science education is crucial for fostering genuine learning and mastery of scientific principles (Osborne, 2013). Conceptual understanding involves grasping the fundamental ideas and relationships that underpin scientific phenomena. When students develop a strong conceptual foundation, they can make connections between different concepts, identify patterns, and explain phenomena using scientific reasoning (Díaz et al., 2021). As per Jamil et al. (2023), this deeper understanding enables students to engage more meaningfully with science, critically analyze information, and make informed decisions based on evidence.

Ultimately, while rote learning may provide short-term memorization of facts, it often hinders long-term retention and application of scientific knowledge. In contrast, promoting conceptual understanding in science education empowers students to become proficient problem-solvers and lifelong learners who can navigate complex scientific concepts with confidence and proficiency. Therefore, educators should prioritize strategies that emphasize conceptual learning and encourage students to explore scientific concepts through inquiry, experimentation, and meaningful engagement with the subject matter.

Peer Collaboration and Knowledge Sharing

Peer collaboration offers significant benefits in science education, particularly for students facing language barriers or challenges in comprehension (Booyoesen, 2023). By engaging in collaborative learning activities, students have the opportunity to interact with peers, exchange ideas, and collectively construct an understanding of scientific concepts. Here are some key benefits of peer collaboration in addressing language barriers and promoting comprehension:

Language Development: Peer collaboration encourages students to communicate and discuss scientific ideas in a supportive environment (Won et al., 2015). Through interactions with peers, language-minority students can practice using scientific vocabulary and expressions, improving their language proficiency over time.

Conceptual Understanding: Collaborative learning promotes deeper comprehension of scientific concepts. Billingsley and Heyes (2022) pointed out that when students work together to solve problems or explain phenomena, they gain different perspectives and insights, which can enhance their overall understanding of complex scientific principles.

Critical Thinking Skills: Working collaboratively encourages students to think critically and analysed information. By discussing ideas with peers, students learn to evaluate evidence, challenge assumptions, and justify their reasoning, which are essential skills for scientific inquiry (Matuk & Linn, 2023).

Increased Engagement: Peer collaboration promotes active participation and engagement in learning (Qureshi et al., 2021). Students are more likely to stay motivated and interested when they have opportunities to collaborate, share responsibilities, and contribute to group outcomes.

Overall, peer collaboration in science education not only helps students overcome language barriers but also enhances comprehension, communication skills, and critical thinking abilities. By harnessing the power of peer interaction, educators can create inclusive learning environments that empower all students to succeed in science.

Previous Research on Peer-Assisted Learning

Peer-assisted learning (PAL) models have been extensively studied and shown to have positive impacts on academic performance across various educational settings, including science education (Guraya & Abdalla, 2020). PAL involves students working together in pairs or small groups to achieve specific learning objectives. Some key findings from research on peer-assisted learning and its impact on academic performance:

Improved Understanding and Retention: Studies have consistently demonstrated that students engaged in peer-assisted learning experience improved understanding and retention of course material (Zhang & Maconochie, 2022). Through collaborative discussions and explanations, students deepen their comprehension of concepts and are better able to recall information during assessments.

Enhanced Problem-Solving Skills: Peer-assisted learning encourages active problem-solving and critical thinking. When students collaborate on tasks or projects, they develop skills in analyzing problems, exploring solutions, and evaluating outcomes, which contribute to overall academic success (Graesser et al., 2018).

Increased Motivation and Engagement: Working with peers can boost student motivation and engagement in learning. Students often feel more comfortable asking questions or seeking clarification from peers, leading to a more positive and interactive learning experience (Tiffany et al., 2023).

Positive Social Interactions: Peer-assisted learning fosters positive social interactions among students. Collaboration promotes communication skills, teamwork, and empathy, creating a supportive learning environment where students feel valued and respected by their peers (Dyson et al., 2020).

Reduction in Achievement Gaps: PAL has been shown to reduce achievement gaps among students from diverse backgrounds. When students with varying levels of academic proficiency work together, they benefit from shared perspectives and collective problem-solving, leading to more equitable academic outcomes (Alam & Mohanty, 2023).

Overall, research supports the effectiveness of peer-assisted learning models in improving academic performance across subject areas, including science. By leveraging peer interactions and collaborative learning experiences, educators can enhance student learning outcomes and promote a positive classroom culture conducive to academic success.

Collaborative learning facilitates deeper understanding and mastery of scientific concepts. When students work together to explore scientific phenomena, they can share ideas, ask questions, and construct knowledge collaboratively. Peer collaboration encourages active engagement with concepts through dialogue and reflection, allowing students to connect theoretical knowledge with real-world applications (Avcı et al., 2019). By explaining concepts to peers and receiving feedback, students develop a clearer grasp of scientific principles and improve their ability to apply knowledge in diverse contexts.

Cole (2014) asserts that in science education, peer collaboration is particularly effective for promoting concept mastery while simultaneously supporting language acquisition. By integrating peer interactions into instructional practices, educators can create inclusive learning environments where students not only develop scientific understanding but also strengthen their language skills through meaningful interactions and collaborative exploration of scientific ideas. This approach enhances student engagement, promotes academic achievement, and fosters a deeper appreciation for the interconnectedness of language and science concepts.

Gaps in Current Research and Study Rationale

The literature may have limited exploration of peer collaboration strategies in Grade IX science education for language-minority students. Peer-assisted learning models, which have demonstrated effectiveness in other contexts, may not have been extensively studied within this specific demographic. Moreover, bridging the gaps in the literature on Grade IX science education in language-minority settings is essential for advancing educational equity, enhancing academic achievement, and guiding evidence-based instructional approaches that support the diverse learning needs of students in this demographic. This study is important for contributing new knowledge and insights that can inform effective teaching strategies and ultimately promote educational success for language-minority students in Grade IX science education.

Theoretical Framework and Conceptual Underpinnings

In the context of peer collaboration, Vygotsky's theory suggests that students can achieve higher levels of understanding and skill development when they collaborate with peers who are slightly more advanced or experienced than themselves (Verenikina, 2003). Understanding scaffolding and the Zone of Proximal (**Figure 1**)

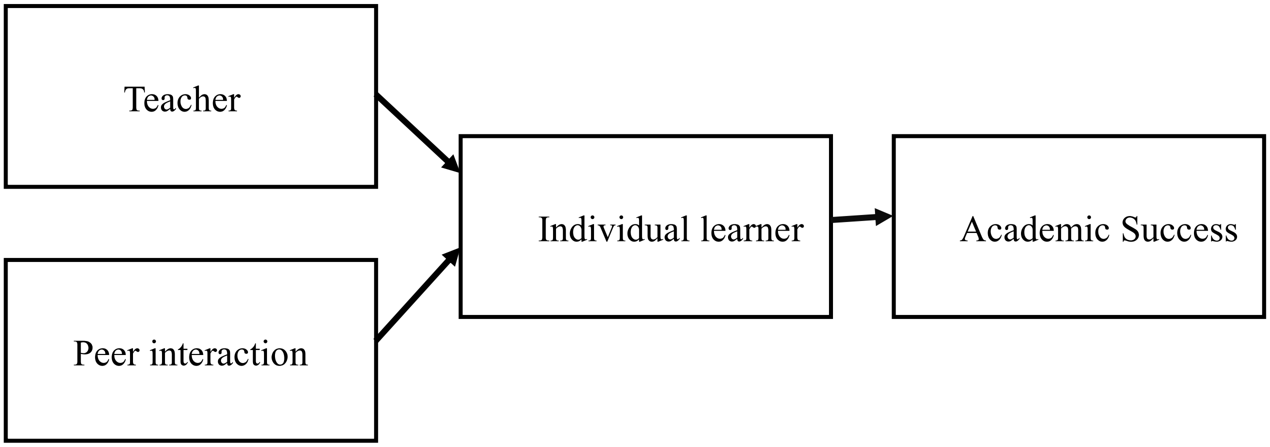

Figure 1. Conceptual framework (Source: Author)

Development in Educational Research

This concept aligns with the idea of peer-assisted learning, where students work together to solve problems, explain concepts, and support each other's learning. By applying the ZPD in peer collaboration strategies, educators can structure activities that facilitate productive interactions between students. For example, assigning tasks that require cooperative problem-solving or encouraging peer tutoring can leverage the ZPD to promote cognitive growth and concept mastery. Peers can provide valuable assistance and explanations that bridge the gap between what students can do independently and what they can achieve with guidance, ultimately fostering deeper comprehension and skill development. Consequently, incorporating Vygotsky's Zone of Proximal Development into peer collaboration approaches can enrich science education by capitalizing on the benefits of social interaction and collaborative learning. This theoretical framework underscores the importance of peer support and scaffolding in facilitating student learning and aligns with the goal of promoting meaningful engagement and comprehension of scientific concepts through cooperative interactions among students.

Methodology

Study Design

The study design selected for this action research is a convergent parallel mixed-methods approach with a quasi-experimental nature. This design allows for the integration of quantitative and qualitative data collection and analysis methods to comprehensively investigate the impact of peer collaboration interventions on science academic performance among Grade IX students at Tangmachu Central School in Lhuentse, Bhutan. By employing a convergent design, the study aims to converge findings from both quantitative assessments of academic performance and qualitative insights from observations, surveys, and interviews, providing a nuanced understanding of the research questions within the specific educational context.

Competence

The research team at Tangmachu Central School comprises educators with a robust background in action research and educational scholarship. As a department, the team has previously conducted four action research projects and successfully published one study, demonstrating a strong foundation in research methodology and academic inquiry.

Furthermore, three members of the team have completed master's degrees, which required the completion of dissertations as part of their academic criteria. This academic achievement signifies their advanced understanding of research principles and their ability to contribute to scholarly discourse in education. All team members have actively engaged in action research over the years, fostering expertise in designing, implementing, and analysing educational interventions. Their collective experience and confidence in conducting research make them well-equipped to undertake and manage the current study on enhancing science education at Tangmachu Central School.

Despite facing challenges with English language proficiency, the participating students at Tangmachu Central School exhibit the capacity to provide authentic data if questions are presented to them clearly. With guidance and support from teachers during the data collection process, these students can confidently contribute to the study.

The students' ability to comprehend and respond accurately, given appropriate explanations and guidance, underscores their potential to contribute valuable insights to the research. By leveraging effective communication strategies and providing necessary scaffolding, the teachers can ensure the meaningful participation of all students in the study, enriching the quality and relevance of the data collected.

Participants

The participants in this study were Grade IX students enrolled at Tangmachu Central School. There were two sections of in grade IX with a total of 54 students. The whole population sampling was employed to ensure that there are no sampling errors or bias. Two sections of students were divided into control and experimental group based on their performance in the pre-test. The control group received standard science instruction as per the existing school curriculum, while the experimental group was engaged in structured peer collaboration activities aimed at enhancing science comprehension and academic performance.

Data Collection

Quantitative data was collected through pre-test and post-test achievement test administered to both the control and experimental groups to measure the impact of the intervention strategy. The achievement test questions were developed by the subject teacher and the construct validity was performed by the research team. Additionally, a survey questionnaire was administered to the experimental group to capture perceptions and experiences towards the use of the intervention strategy after the intervention. In addition, qualitative data was collected through focused group interviews exclusively with participants from the experimental group to explore their views and reflections on peer collaboration in science education. The interview was conducted by the team of researchers.

Analysis

The achievement test data was analysed using an independent sample t-test to compare the academic performance between the control and the experimental group after two months of intervention. This analysis was aimed to investigate the impact of the intervention strategy in learning science for grade IX students. Moreover, to ensure the growth of the academic competence of the students, a paired sample t-test was also performed both for control and experimental group.

The qualitative data collected through focused group discussion was analysed using thematic analysis to draw themes and patterns to understand their perception and experiences of the intervention strategy in learning science. Moreover, themes and patterns drawn from the qualitative analysis were also important in suggesting recommendation for the educators who wish to follow the same strategy in teaching and learning process.

Ethical Consideration

Ethical guidelines were strictly followed to ensure the integrity of the study and the well-being of all participants. Prior to data collection, informed consent was obtained from both students and their parents or guardians, ensuring they were fully aware of the study's purpose, procedures, and potential benefits or risks. Participation was voluntary, and students were given the freedom to withdraw at any stage without any negative consequences.

To maintain confidentiality and anonymity, all participants' identities were kept confidential. No personal identifiers were used in data analysis or reporting. The collected data was securely stored and accessible only to the research team.

In addition, the study ensured fair treatment of participants by maintaining equal opportunities for both the experimental and control groups. The intervention was designed to minimize harm and maximize benefits, ensuring that no student was disadvantaged. The research adhered to academic integrity and objectivity, avoiding bias in data collection, analysis, and reporting.

Intervention Plan: Implementing Peer Collaboration Using the TPGA Method

The intervention plan aims to train Grade IX teachers (teaching chemistry, biology, and physics) at Tangmachu Central School to effectively employ peer collaboration strategies in their classrooms using the TPGA method (Teacher, Pair, Group, and Assessment) to enhance student learning outcomes.

The intervention was carried out for a period of two months, starting from May 1st to the end of June 2024. During the intervention period, all the sessions for the experimental group were facilitated following the steps of the TPGA method and the control group of students were taught using the traditional method, which most of the time included lecture method.

The science subject teachers (chemistry, biology, and physics) were oriented on the process of the intervention before it was implemented in the class to ensure uniform instructions to the students. The steps of the TPGA method employed for this study is indicated in **Figure 2**.

As indicated in **Figure 2**, the implementation of the TPGA method followed a structured sequence of instructional and collaborative stages. The process began with Topic Introduction, where teachers introduced a specific topic or concept during regular classroom sessions to establish a foundation for learning. This was followed by Pair Discussion, in which students engaged in dialogue with a partner to share their understanding and insights on the topic. Subsequently, during the Group Discussion stage, students formed small groups to further explore the concept, exchange ideas, and collaboratively solve problems or complete related tasks.

Throughout these peer collaboration activities, teachers engaged in Monitoring and Correction, moving around the classroom to observe discussions, clarify misconceptions, and provide constructive feedback to ensure conceptual accuracy and understanding. Finally, the process concluded with Individual Assessment, where teachers assigned individual tasks or assessments to evaluate each student’s comprehension and mastery of the topic covered.

Compensation for Control Groups

To compensate for the lack of peer collaboration in the control groups, teachers implemented similar peer collaboration strategies during revision sessions for other topics outside the intervention period. This ensures that all students have the opportunity to benefit from collaborative learning experiences throughout the study duration.

Results and Discussion

Demographic Information

The study participants comprised students studying biology, chemistry, and physics in grade IX. In total, 54 participants (33.4% male, 66.6% female) were selected, and 27 participants were selected for the intervention and survey questionnaire as indicated in **Table 1**. Besides, a total of nine students were selected randomly to participate in the face-to-face semi-structured interview.

Achievement Test

To compare students' learning achievement, pre- and post-tests were administered before and after the intervention for both the EG and the CG. The test question consists of two sets of questions: 6 multiple-choice questions (MCQ) and 7 conceptual questions. For this study, a mixture of questions was chosen to check the breath of understanding and depth of knowledge (Bentley et al., 2023). The pretest was intended to examine the learning abilities and background knowledge of the participants for both groups. Similarly, the post-test was intended to find the differences in learning achievement after the completion of the intervention. To find the statistically significant difference between the groups, an independent t-test was conducted. For both statistical tests, the significance level was set at 0.05.

The comparison of the mean and standard deviation of pre-test and post-test between both the experimental and control groups is presented in **Table 2**. As indicated in **Table 2**, the pre-test mean score for EG (M=3.5) which is equal to CG (M=3.5). Also, the EG (SD=1.63) has slightly more variation than the CG (SD=1.53). The equal value of mean and standard deviation suggests that before the intervention, the learners had similar achievement. To validate whether there is any significant difference between the mean scores of the groups, an independent samples t-test was conducted.

The result indicated that there is no significant difference in the achievement between the EG and CG, as the calculated significance value(P) was .24, which was greater than significant value P<.05. Therefore, it confirmed that both the groups had same learning abilities before the treatment. Arithmetic mean of post-test is presented for both the groups, and the results are recorded in **Table 2**. The post-test mean score for EG *(M= 11.7)* is greater than CG *(M=8.4)*. The mean difference between EG and CG was *(MD=3.3)*. This shows that students who received instruction on peer collaboration achieved more score than those taught through conventional method. The higher mean score of the EG was attributed to the effective use of peer collaboration while learning Science subject in grade nine.

To confirm whether there is significant difference in achievement between EG and CG and to authenticate the impact of peer collaboration to EG, independent samples t-test was conducted to confirm if there is a significant difference in post-test scores of EG and CG. The result indicated that there was a statistically significant difference in post-test in favour of the EG, with the significant value (P)was .004, which was lower than the significant value P<.05.

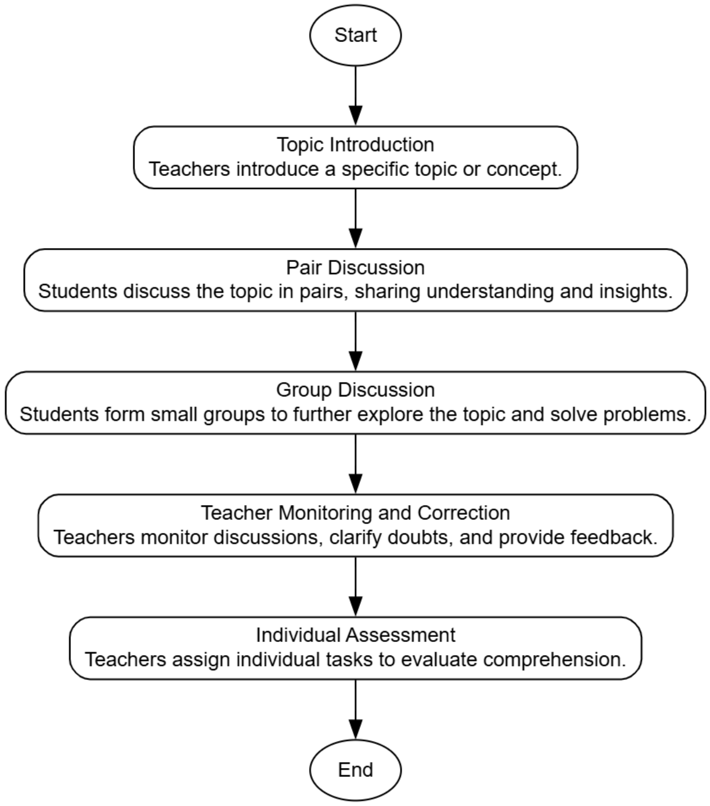

Figure 2. Steps of the TPGA method (Source: Author)

Further **Table 2** shows a comparison of pretest and post-test between C.G and E.G. The pretest scores indicate that both groups started at an identical baseline level, with mean scores of 3.5 for both the C.G and the E.G. This suggests that, prior to the intervention, there was no significant difference in the level of understanding of scientific concepts between the two groups.

The post-test results reveal a notable difference in the performance of the two groups. The mean post-test score for the C.G. increased to 8.4, representing a modest improvement from the pretest. This suggests that the traditional instruction had a positive impact on students' learning, though the increase in scores was relatively moderate. In contrast, the EG exhibited a marked improvement, with a mean post-test score of 11.7.

This substantial increase, compared to the control group, suggests that peer collaboration had a significantly greater effect on students' understanding of the science content. These results align with previous studies on the benefits of peer collaboration in learning science. According to Mishra (2023), social constructivist theory, learning occurs more effectively through interaction with peers, as it allows students to construct knowledge by engaging in dialogue, questioning, and shared problem-solving. Peer collaboration fosters an environment where learners can exchange ideas, clarify misconceptions, and build deeper conceptual understanding.

Research by Qureshi et al. (2021) supports the idea that collaborative learning enhances academic achievement compared to individual or competitive learning. Their study found that students working in small groups tend to retain information better and develop critical thinking skills more effectively, which could explain the superior performance of the experimental group in the post-test. Additionally, Bahufite et al. (2023) emphasized that peer interaction in science learning promotes not only cognitive understanding but also motivation and confidence, both of which contribute to higher academic performance.

Table 1. Class IX student respondents

Gender	Frequency	Percentage
Male	18	33.4%
Female	36	66.6%
Total	54	100%

Table 2. Comparison of pre-test and post-test between the groups (independent sample t-test)

Test	Group	N	Mean	Mean Difference	Std. Deviation	Sig.(2 tailed)
Pre-test	Experiment	27	3.5	0.00	1.63	.243
	Control	27	3.5		1.53	
Post-test	Experiment	27	11.7	3.30	2.75	.004
	control	27	8.4		3.08	

The Control Group's moderate improvement is consistent with studies indicating that traditional, teacher-centered instruction can lead to gains in knowledge but may not provide the same depth of understanding as collaborative learning environments (Dada et al., 2023). Traditional methods often emphasize the transmission of knowledge rather than its construction, which may explain the lower post-test scores in the control group compared to the experimental group.

Students' opinions towards Peer Collaboration

The survey questions provide insight into students' perceptions and experiences of peer collaboration in their Grade 9 science class.

Engagement in Peer Collaboration Activities

As mentioned in **Figure 2**, the responses indicate that the majority of students, around 16 respondents, engage in pair discussion activities. A smaller number of students reported engaging in peer tutoring. This suggests that structured or consistent peer interaction could be encouraged to enhance learning outcomes. The interview responses largely supported the results, highlighting why pair discussions are the most frequently used and preferred form of collaboration.

Many students expressed a strong preference for pair discussions due to the comfort and simplicity of working with just one peer. As one student explained, *"When I discuss with just one person, it's easier to focus, and I feel less pressure compared to working in a larger group."*

This aligns with the findings of Tahir (2023), who suggests that pair or small group discussions are often preferred by students as they offer a low-pressure environment conducive to knowledge sharing and idea exchange. Pair discussions are particularly effective in enhancing comprehension, as they allow students to clarify concepts with their peers, leading to a deeper understanding (Fakoya et al., 2023).

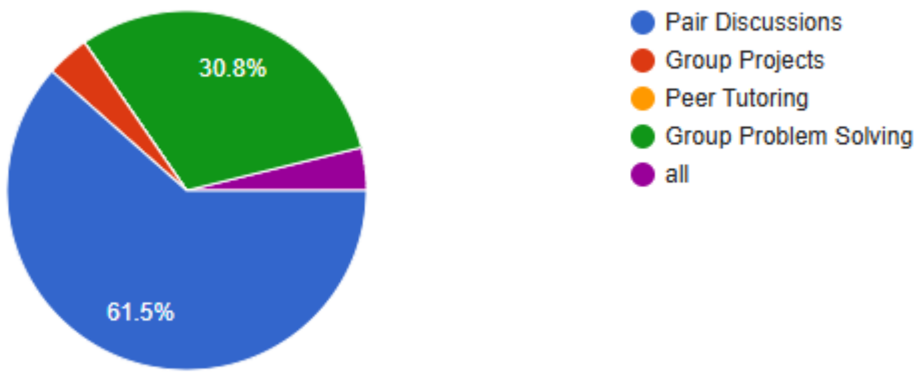

Figure 2. Pie chart showing engagement in peer collaboration (Source: Author)

Perception of Peer Collaboration

Figure 3 shows that majority of students, around 11 respondents out of 29, reported feeling "Positive" about working with their peers. Another large group expressed "Neutral" feelings, and a smaller subset, approximately 4 respondents, reported feeling "Very Positive." These findings suggest that peer collaboration is generally viewed positively and engage all students. These sentiments were further explored in interviews, which revealed several factors influencing students' perceptions. Many students who selected Positive or Very Positive responses indicated that peer collaboration activities, such as pair discussions and group problem-solving, helped them clarify concepts and improve their understanding of difficult topics. One student shared, "Working with classmates helps me see things from a new perspective, which I think is really valuable." This finding is consistent with the broader body of research that suggests collaborative learning enhances student engagement, motivation, and understanding, particularly in STEM fields (Fakoya et al., 2023).

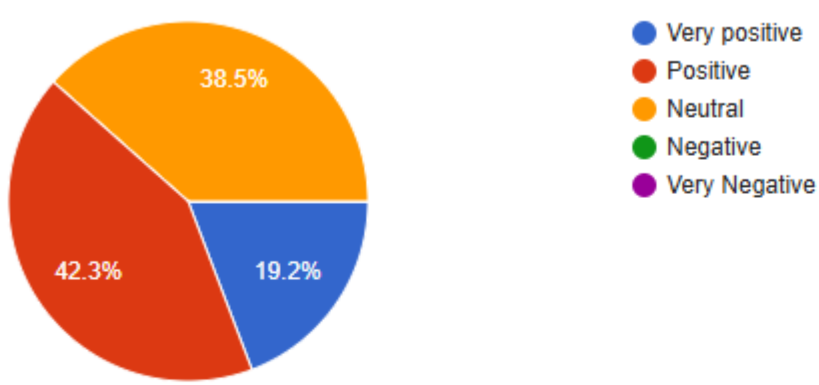

Figure 3. Comparison of students' perception (Source: Author)

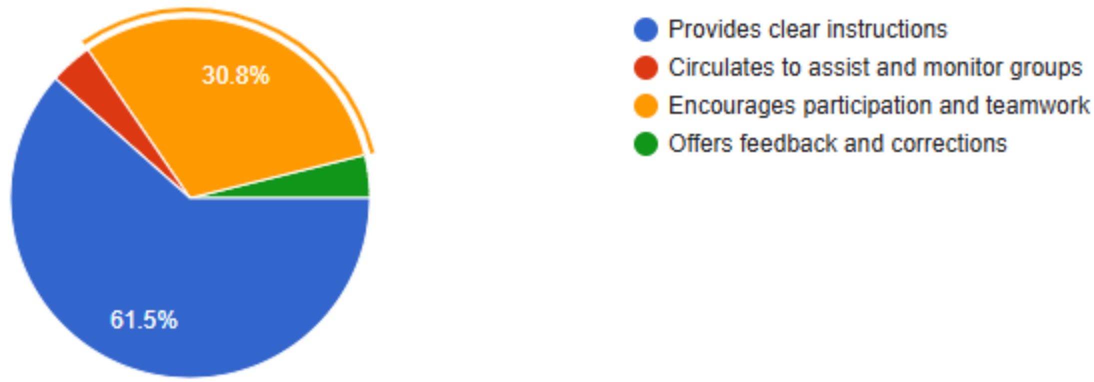

Figure 4. Different level of teacher support (Source: Author)

Teachers' Support and Engagement

The ratings show the largest portion of the teacher's engagement is dedicated to providing clear instructions. This suggests that a significant priority is placed on ensuring that students have a clear understanding of tasks and expectations during collaborative activities. It aligns with best practices in science education, where clear procedural and conceptual guidance is essential for effective inquiry-based learning. Interviews with students provided further insight into these findings. Many students echoed the need for clear instructions as critical to the success of peer collaboration. One student remarked, "When the teacher explains exactly what we need to do, we don't waste time figuring out our tasks, and we can focus more on the discussion."

As shown in **Figure 4**, the largest portion of the teacher's effort (61.5%) is dedicated to providing clear instructions, indicating the teacher's focus on ensuring clarity and understanding before students engage in collaborative tasks. This aligns with research by Johnson and Johnson (2017), which emphasizes that clear instructions and structured expectations are foundational for successful group work. Such an approach ensures that students are aware of task objectives, reducing cognitive load and facilitating smoother collaboration (Cheng et al., 2021).

Conclusion

The study analysed students' science achievement test scores and their perceptions of peer collaboration in a Grade 9 science class. The quantitative data revealed that both the experimental group (EG) and control group (CG) started with similar pre-test scores (M=3.5). However, after peer collaboration intervention, the EG outperformed the CG in the post-test (M=11.7 vs. M=8.4), with a statistically significant difference (p=0.004). The qualitative data indicated that students generally had a positive perception of peer collaboration, preferring pair discussions. Teachers' support mainly focused on providing clear instructions, which students found beneficial.

The findings highlight the effectiveness of peer collaboration in improving students' learning outcomes in science. The EG's significantly higher post-test scores suggest that engaging in structured peer interactions helped students understand concepts more deeply. This aligns with Vygotsky's social constructivist theory, which emphasizes the role of peer learning in cognitive development.

Students' preference for pair discussions suggests that smaller, less intimidating peer interactions create a comfortable learning environment. However, the neutral responses from some students indicate that peer collaboration might not be equally effective for everyone, possibly due to personality differences or prior experiences. Teachers' emphasis on clear instructions demonstrates their awareness of the importance of structure in collaborative learning. The findings from this study reveals the power of TPGA method, further standardising the process of guided peer discussion to enhance science learning for students.

Recommendations

Based on the findings, educators should consider enhancing peer collaboration by incorporating structured roles and responsibilities within group work to ensure active participation from all students. Moreover, educators should also incorporate the system to support diverse student preferences by offering multiple collaboration formats (e.g., structured peer tutoring, mixed-ability groups) to accommodate different learning styles. In this study, groups comprised of mixed genders were involved in peer collaboration and therefore the effectiveness of single gender peer collaboration could not be studied. Therefore, this study recommends future studies to focus on gender-based peer collaboration and its potential to enhance science learning.

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Ethical statement: The study was conducted in accordance with the ethical standards of the Ministry of Education and Skills Development, Bhutan. Informed consent was obtained from all participants involved in the study.

AI statement: AI tools were used solely for language editing and proofreading. The author takes full responsibility for the content and interpretation of the manuscript.

Data Sharing Statement: The data supporting the findings of this study are available from the author upon reasonable request.

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Appendix

Survey Questionnaire: Peer Collaboration in Science Education

Dear Student,

Thank you for participating in this survey to gather your perceptions and experiences regarding peer collaboration in science education. Your feedback is valuable in helping us understand how peer collaboration impacts your learning. Please answer the following questions honestly and to the best of your ability.

Demographic Information:

Gender: [ ] Male [ ] Female [ ] Other

Age: ____________ years

Grade: Grade IX

Peer Collaboration Experience: 4. How often do you engage in peer collaboration activities in your science class?

Never

Rarely

Sometimes

Often

Always

What types of peer collaboration activities have you participated in? (Check all that apply)

Pair discussion

Group projects

Peer tutoring

Group problem-solving

Other (please specify): _________________

Perceptions of Peer Collaboration: 6. How do you feel about working with your peers to learn science concepts?

Very positive

Positive

Neutral

Negative

Very negative

What do you believe are the benefits of peer collaboration in science education? (Select all that apply)

Helps clarify difficult concepts

Encourages critical thinking

Promotes teamwork and communication skills

Provides different perspectives on topics

Builds confidence in learning

Other (please specify): _________________

How does peer collaboration impact your understanding of science topics?

Significantly improves understanding

Moderately improves understanding

Slightly improves understanding

No impact

Decreases understanding

Teacher Support and Engagement:

9. How does your teacher facilitate peer collaboration activities in the classroom?

Provides clear instructions

Circulates to assist and monitor groups

Encourages participation and teamwork

Offers feedback and corrections

Other (please specify): _________________

Do you feel that your teacher effectively supports peer collaboration in science class?

Yes

No

Not Sure

Overall Experience: 11. On a scale of 1 to 5, how would you rate your overall experience with peer collaboration in science class? (1 = Very negative, 5 = Very positive)

What suggestions do you have for improving peer collaboration in science education at our school?

Thank you for completing this survey. Your responses will contribute to our efforts in enhancing science education through peer collaboration. If you have any additional comments or feedback, please feel free to share them below.

Additional Comments:

Semi-Structured Interview Questions

Experiences with peer collaboration

How would you describe your experience with peer collaboration in science class?
Can you share an example of a peer collaboration activity that you found particularly beneficial or enjoyable?

Benefits of peer collaboration
What do you believe are the advantages of working with your peers to learn science concepts?
In what ways does peer collaboration contribute to your understanding of challenging science topics?

Challenges and opportunities
What challenges have you encountered while participating in peer collaboration activities?
How do you think these challenges can be addressed to enhance the effectiveness of peer collaboration?

Teachers' roles in peer collaboration
How does your teacher facilitate peer collaboration activities in the classroom?
What strategies or approaches does the teacher use to support peer interactions and learning?

Impact on Learning and Engagement:
How has peer collaboration influenced your engagement in science class?
Do you feel that peer collaboration has helped you grasp scientific concepts more effectively compared to traditional teaching methods?

Communication and Teamwork:
How do you communicate and collaborate with your peers during group discussions or projects?
What role does teamwork play in achieving shared goals during peer collaboration activities?
Reflections and Suggestions:
Looking back on your experiences with peer collaboration, what are your reflections or key takeaways?
Do you have any suggestions for improving peer collaboration in science education at our school?

Participant Consent Form

Title of the Study: *The Impact of Peer Collaboration on Science Achievement in Grade 9*

Introduction: You are invited to participate in this research study conducted by science department. The purpose of this study is to examine how peer collaboration influences science learning. Your participation is voluntary, and you may withdraw at any time without consequences.

What Will You Be Asked to Do?

Participate in regular science lessons.

Complete a pre-test and post-test.

Engage in peer collaboration activities (if selected for the experimental group).

Answer a short survey and/or interview about your learning experience.

Confidentiality and Anonymity:

All information you provide will be kept confidential. Your name and personal details will not be disclosed in any reports or publications.

Potential Risks and Benefits: There are no known risks associated with this study. The findings may help improve science teaching methods and benefit future students.

Consent Statement:

By signing below, I confirm that:

I have read and understood the study details.

I voluntarily agree to participate.

I understand that I can withdraw at any time.

Participant's Name: ___________________________
Signature: ___________________________
Date: ___________________________

Parent/Guardian's Name (if participant is under 18): ___________________________
Signature: ___________________________
Date: ___________________________

Researcher's Name: ___________________________
Signature: ___________________________
Date: ___________________________