Assessing the Impact of Experiential Learning with Collaborative Teaching on Mathematics Achievement of Deaf Learners in Non-Inclusive Classrooms

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Abstract

This quasi-experimental study evaluated the impact of experiential learning with collaborative teaching strategies on the deaf students' mathematics achievement in exclusionary classroom settings. Using an ANCOVA statistical model, the study contrasted post-test outcomes for 54 deaf students equally divided into an experimental ($n = 27$) taught with experiential-collaborative techniques and a control group ($n = 27$) taught with traditional instruction, controlling for pre-test performance. Analysis revealed that there was a statistically significant difference in post-test mathematics performance between the groups, $F(1, 51) = 22.426$, $p < 0.001$, with a large effect (partial $\eta^2 = 0.305$). The experimental group significantly scored higher on the adjusted mean post-test score ($M = 26.38$, $SE = 1.06$) compared to the control group ($M = 19.17$, $SE = 1.06$), with a mean difference of 7.21 ($p < 0.001$). These findings verify the effectiveness of experiential learning combined with cooperative instruction to enhance mathematical achievement in deaf students in specialized (non-inclusive) education environments. The results have strong implications for planning and delivery of instruction in approaches responding to deaf students' unique learning needs.

Introduction

Mathematics is traditionally defined as a foundational subject that is taught as an essential component of rational thinking, problem-solving, and academic achievement across all disciplines (Choe, 2024). For deaf pupils, however, to be mathematics literate generally entails specific and cumulative challenges, especially in non-inclusive or specialist learning settings where communication problems, concomitantly restricted instructional bandwidth and absence of inclusive pedagogic methods may impede effective learning (Bowman & Crowe, 2023; Crowe, 2022; Marschark & Hauser, 2012). Despite efforts to individualize teaching in schools for the deaf, teacher-centered approaches remain the norm with a lot of focus on rote memorization and limited student interaction (Hatsu, Boateng, Arthur, & Akosah, 2025).Such approaches have not been bringing notable mathematical progress among the deaf students, suggesting the need to insist on adopting new, evidence-informed pedagogies that would be appropriate to the cognitive and communication needs of the students (Yang, Chen, He, Sun, & Salas-Pilco, 2024).

One such approach being studied by researchers and implemented in practice is experiential learning, which emphasizes active engagement and reflection as key to the process of gaining knowledge (Kolb, 1984). Experiential learning enables learners to construct mathematical knowing through direct interaction with real-world tasks, manipulatives, and problem-solving situations. For deaf students, this approach offers visual and kinesthetic routes to meaning-making, which can bypass linguistic limitations and support more profound conceptual understanding (Theofield, 2023). But experiential learning may not be enough to fill in the communication, collaboration, and support instructional needs required in special classrooms. (Efendi, 2024).

To bridge this chasm, co-teaching two or more instructors planning, teaching, and assessing students together, has been found to be a complementary strategy augmenting the learning milieu with diverse expertise and interactive participation (Kim, 2024). In deaf students' classes, co-teaching is frequently conducted by content specialists and sign language interpreters or special education teachers co-teaching. This collaborative mode not only supports access but also enables more rich discourse in instruction, one-on-one scaffolding, and mechanisms of feedback (Yi, Sintawati, & Zhang, 2025). Combined with experiential learning, collaborative instruction can optimize the impacts of experiential activities through collective reflection, supported practice, and dialogical interaction (Ciddi, 2025; Gong, Kwon, & Brock, 2022; Kučerová, 2023; Luzano, 2025; Oliveira & Pombo, 2017; Vale & Barbosa, 2021). Despite the theoretic promise of their combination in experiential learning with collaborative teaching, their combined empirical influences in non-inclusive settings for the deaf students have not been researched (Mantey, 2021). The majority of the studies conducted so far focus on inclusive settings or on either of these methods singly. Furthermore, few studies have employed strict experimental designs and statistical control to isolate instructional effects from other confounding factors such as prior attainment (Gopalan, Rosinger & Ahn, 2020). In light of the long-established achievement gap in mathematics for deaf students, and the inability of traditional methods to diminish the gap, it is important to explore how various pedagogies perform in practice (Zongozzi, & Ngubane, 2025).

This study fills this gap by experimentally assessing the impact of experiential learning integrated with team instruction on deaf students' mathematics attainment in non-inclusive classrooms. Using an Analysis of Covariance (ANCOVA) design, the study controls for baseline levels of attainment to obtain a cleaner estimate of the instructional effect. The findings not only offer theoretical input to instructional design and deaf education research but also offer practical implications for curriculum developers, educators, and policymakers trying to optimize mathematics learning outcome in specialist schools.

Statement of the Problem

Despite growing demands for inclusive learning, most deaf pupils continue to be taught in non-inclusive (special) classes, where teaching methods remain largely conventional, teacher-centered, and abstract in nature. This has produced ongoing challenges for deaf pupils in their academic performance in mathematics, since they tend to struggle to understand concepts and stay motivated within these classroom environments. Traditional pedagogical methods of inclusive classrooms do not usually provide deaf students with deaf students' multisensory, interactive, and participatory learning experiences that deaf students require to learn mathematics effectively (Luvanga, 2021). Experiential learning, coupled with collaborative teaching methods, can ensure clear concepts and active students' involvement. (Pahi, Hawlader, Hicks, Zaman, & Phan, 2024). But strong empirical evidence still lags, especially from controlled experiments on the effectiveness of such methods in precisely non-inclusive classrooms for deaf students. This research problem is compounded as well by the minimal use of statistical methods such as ANCOVA to adjust for initial differences in accomplishment and purify the effect of novel instructional interventions. Therefore, there is a strong need to establish whether experiential learning, when organized through cooperative pedagogical models, will increase the mathematics achievement of deaf students in specialized classrooms beyond that resulting from traditional approaches.

Theoretical Review

Kolb's Experiential Learning Theory (1984) sees learning as a circular process. Knowledge comes from concrete experience, reflective observation, abstract conceptualization, and active experimentation. This model stresses learning by doing. It is particularly important for deaf learners, who gain from visual, tactile, and participatory methods. In mathematics education, ELT helps deepen understanding by involving learners in hands-on activities that encourage active participation and thoughtful reflection. For deaf learners in non-inclusive classrooms, this theory lays a solid groundwork for teaching strategies that focus on accessible, meaningful, and interactive learning experiences. Collaborative teaching can further improve these experiences by providing extra support for reflection, idea formation, and application.

Empirical Review

Over the past two decades, research has increasingly focused on how teaching methods can support deaf learners' academic achievement, especially in mathematics. This subject often presents cognitive and language challenges for these students. Among these methods, experiential learning (EL) and collaborative teaching (CT) have shown promise. However, while current studies emphasize the benefits of EL and CT in inclusive classrooms and general education, there is still a lack of research specifically addressing non-inclusive settings. Therefore, this review looks closely at studies on experiential learning, collaborative teaching, and mathematics instruction for deaf learners, aiming to identify gaps that warrant further investigation.

Experiential Learning in Mathematics Education for Deaf Learners

To start, many studies show that experiential learning can lead to a deeper understanding and greater engagement among deaf students. For example, Marshall *et al*. (2016) and Carrano *et al*. (2014) used mixed-methods approaches to analyze the effects of experiential learning on problem-solving among deaf engineering students. Their findings indicated that experiential learning significantly improved cognitive engagement and the use of abstract concepts. However, these studies were conducted in post-secondary STEM programs, which limits their relevance for younger learners' mathematics achievement in non-inclusive classrooms. Similarly, Adeniyi and Kuku (2020) used a quasi-experimental design to assess gamified experiential learning among hearing-impaired students in Lagos. Their results showed significant improvements in mathematics scores, supporting the effectiveness of experiential learning. Yet, because the study occurred in a partially inclusive context, its relevance for fully segregated classrooms remains limited.

Additionally, Amril and Juandi (2020) examined the EL-CPA (Concrete-Pictorial-Abstract) model and its effect on deaf learners' attitudes toward mathematics. While their findings were positive, the small sample size and lack of control groups weakened the study's generalizability and internal validity. Similarly, Mahayukti and Dewi (2022) looked at discovery-based experiential learning in special junior high schools. Their descriptive findings showed increased motivation and understanding, but the absence of an experimental framework limited the depth of their conclusions. Overall, these studies suggest that experiential learning holds significant potential for improving mathematics outcomes for deaf learners. However, they highlight a recurring issue: most research takes place in inclusive or post-secondary contexts, with few attempts to examine how experiential learning functions in the unique dynamics of non-inclusive classrooms.

Collaborative Teaching and Peer Interaction in Mathematics Learning

Moving past experiential learning, the literature also supports collaborative teaching as a way to improve learning outcomes for deaf students. Abd Algani (2021), for instance, used an experimental design to study the effects of collaborative learning on students' mathematics performance. The study found significant improvements, especially among low-achieving students. However, it is important to note that the participants included students without hearing impairments, which limits the direct relevance of the findings to deaf education. In addition, Lehane and Senior (2020) researched co-teaching practices in inclusive classrooms and discovered that collaborative instruction significantly enhanced numeracy performance for both students with and without special needs. Their findings affirm the benefits of collaborative teaching in inclusive settings, but they do not address whether these benefits extend to non-inclusive classrooms, where team-teaching structures are often missing or changed.

Likewise, El-ahwal (2022) investigated how collaborative media improved special educators' math teaching skills during the COVID-19 pandemic. While this study demonstrated improvements in teacher skills, it did not directly assess student learning outcomes, leaving a gap in understanding the direct impact of collaborative teaching on achievement. Furthermore, literature reviews by Van Garderen *et al.* (2012) and Adigun (2020) discussed the theoretical benefits of collaboration between special and general educators. However, they also pointed out a lack of rigorous studies on the measurable outcomes of such collaborations, especially for deaf learners in non-inclusive contexts. In conclusion, while collaborative teaching seems beneficial, existing studies mainly focus on inclusive settings. Therefore, its practical implementation and measurable impact in segregated, non-inclusive deaf classrooms remain significantly under-researched.

Combined Impact of Experiential Learning and Collaborative Teaching

Notably, only a few studies have examined the synergistic effects of experiential learning and collaborative teaching. For example, Rho *et al*. (2020) tested an experiential learning model via virtual reality for teaching manual communication. While their findings revealed heightened student engagement, the focus remained on communication skills rather than mathematics, and collaboration was technological rather than instructional. Meanwhile, studies by Olaoluwa and Ayantoye (2016) and Yekinni *et al*. (2024) investigated brain-based and peer tutoring strategies for deaf learners. Although both studies showed improved academic outcomes, they did not explicitly integrate experiential learning principles, nor did they systematically test the combination of CT and EL in mathematics instruction.

Similarly, Kliziene *et al.* (2024) and Suarsana et al. (2018) found that gamified and media-rich learning environments supported deaf learners' performance. However, their methodologies lacked control conditions or did not clearly differentiate between individual and collaborative efforts, making it difficult to isolate the effects of combined EL and CT approaches. Therefore, although the separate benefits of EL and CT are increasingly recognized, the lack of studies investigating their integrated impact in non-inclusive mathematics classrooms for deaf learners represents a significant empirical gap, one which this study aims to address.

Studies on Deaf Learners' Challenges and Contextual Factors

Equally important is understanding the context-specific challenges that deaf learners face in mathematics. For instance, Bashir *et al*. (2024) and Manchishi (2015) documented the cognitive difficulties deaf students encounter when dealing with abstract mathematical concepts. These difficulties are often worsened by inadequate instructional adaptations and a lack of visual or kinesthetic teaching strategies. Furthermore, Murungi *et al*. (2025) and Kathare (2020) emphasized the importance of teachers' instructional strategies in shaping academic performance. However, these studies employed correlational or descriptive designs, which, although informative, fall short of establishing causal relationships between specific pedagogical approaches and learner achievement.

Likewise, Goldstein (2017) and Chishimba (2016) explored the influence of mathematics identity and teacher awareness on learning outcomes among deaf learners. These studies provided valuable insights into the attitudinal and sociocultural dimensions of learning but did not examine how structured interventions such as EL or CT might influence these factors. Taken together, these studies underscore the multifaceted barriers that hinder mathematical achievement among deaf learners, while also reinforcing the need for pedagogically sound, empirically validated interventions, particularly in settings where learners are segregated from their hearing peers.

Methodology

Research Design

This study employed quasi-experimental pre-test–post-test control group design to determine the effectiveness of experiential learning with collaborative teaching in improving deaf students' performance in mathematics. The primary objective was to assess the effect of experiential learning integrated with collaborative teaching on the mathematics achievement of deaf learners in non-inclusive (specialized) classroom settings. The use of

ANCOVA allowed for the statistical control of pre-existing differences in learners' baseline performance, ensuring that post-test outcomes could be more accurately attributed to the instructional intervention.

Experiential learning activities were designed in accordance with the learning objective as outlined in the basic school mathematics curriculum. In this case, the learners were engaged with those experiential learning activities that had been designed by the basic school teachers and the researcher. As the activities were being done, the students were given an opportunity to sense and live real learning activities within and beyond classroom. Experiential learning activities were designed on the concept of statistics (finding the mean from frequency distribution tables) and fractions and other mathematics topics taught with the three months. Exercises were not selected from school-supplied books. But students were compelled to describe their own experiences because they go through the learning and teaching process. The teachers were compelled to instruct control-specialized class as well as experimental-specialized class because of their proficiency in the range and content of the basic school mathematics. During experiential learning with collaborative instruction, students were taught by the experiential learning activities designed by the researcher in consultation with mathematics teachers. Prior and subsequent to experimentation, both groups were given mathematics achievement test of what was to be taught during the three months' period of instruction. This was aimed at measuring how the performance of the learners has improved in both groups, within the three months learning and instruction.

Participants and Sampling

A total of 54 deaf learners from a non-inclusive special school participated in the study. The school was selected through purposive sampling based on use of Ghanaian Sign Language as the primary medium of instruction and their willingness to participate in experimental research. Within special school, learners were assigned to either an experimental group ($n = 27$) or a control group ($n = 27$) using intact class assignment to preserve natural classroom dynamics. All participants were in the same grade level and had similar instructional exposure in prior academic years. Learners with multiple disabilities were excluded to ensure a homogenous sample focused solely on deafness.

Research Design and Sample Selection for Implementing Experiential Learning in Teaching Mathematics to Deaf Students

Junior high school form 3 students from the Tetteh Ocloo school for the deaf located at Adjei Kojo in the Ashaiman Municipality of the Greater Accra Region of Ghana constituted the population for this research. The use of purposive sampling method was applied in the selection of students for this research. The students' population from this class (form 3) is fifty-four (54) deaf learners. The school was selected on the grounds of purpose because Tetteh Ocloo State School for the deaf is a special school for the deaf and also use Ghanaian Sigh Language for communication. The fifty-four (54) pupils represented two intact classes of twenty-seven (27) each, one for the control group and the other for the experimental group. All seven Junior High School mathematics teachers of both schools participated in the study to ensure the implementation of experiential learning with collaborative teaching methods.

Experiential learning activities were prepared in collaboration with the seven Junior High School mathematics teachers. This was greatly needed since the teachers were asked to implement the teaching during the experiment. In order not to disrupt class teaching and learning, the research was held on Wednesdays and Fridays at 1 pm for 60 minutes. In control group, students were provided with extra exercises from books which were available for students and teachers. Mathematics instructors of both Junior High Schools provided lessons simultaneously on topics such as statistics and fractions and other mathematics topics to control and experimental groups for three months. Five mathematics teachers were assigned to experimental class and two assigned to control class. All seven teachers were expert in using sign language for lesson delivery.

Intervention Procedure

The experimental group was exposed to experiential learning combined with collaborative teaching a 12-week intervention period (three months). Instruction followed Kolb's Experiential Learning Cycle (concrete experience, reflective observation, abstract conceptualization, and active experimentation) and was implemented through structured, hands-on mathematical activities. Collaborative teaching involved a subject teacher, a special educator, and a sign language interpreter working in tandem to deliver content, facilitate group discussions, and provide individualized scaffolding. Lessons were designed to be visual, tactile, interactive, and problem-solving-oriented, aligning with the cognitive and communication preferences of deaf learners. In contrast, the control group received mathematics instruction through traditional lecture-based methods, delivered by a single teacher without collaboration or activity-based learning strategies. The lesson content across both groups covered identical mathematical topics as prescribed in the national curriculum for the grade level.

Teaching Statistics through Experiential Learning with Collaborative Approaches in Specialized Deaf Classrooms

One of the experiential learning lessons delivered using collaborative teaching approaches was on the topic of *Statistics* for Junior High School Form 3 deaf students in a specialized school setting. The two intact groups: the experimental group, which received instruction through experiential learning with collaborative teaching, and the control group, which was taught through traditional methods. In the experimental class, the lesson followed Kolb's experiential learning cycle to support deep understanding of statistical concepts and active learner participation. The lesson began with a concrete experience, where students engaged in a real-life data collection activity. Collaborative teachers (two subject teachers and a co-teacher using sign language) guided students through a practical task of surveying their classmates on their favorite fruits. Visual aids such as real fruits, picture cards, and labeled signs were used to support understanding and communication. Students, working in small groups, moved around the classroom asking each peer about their favorite fruit using sign language. As responses were gathered, they recorded them using tally marks on prepared data sheets.

Once the data was collected, students were introduced to a frequency distribution table. The collaborative teachers helped each group to organize their data into a structured table with three columns: *Fruit Type*, *Tally*

Marks, and *Frequency*.

The frequency table provided a clear summary of the data collected and supported visual learning, which is essential for deaf students. In the reflective observation stage, students were encouraged to discuss and reflect on the experience of collecting and organizing data. The collaborative teachers guided them in thinking about how the activity was conducted: How did they gather responses? Was communication between group members smooth? Did the use of tally marks and tables help them understand the results better? These reflective discussions, conducted in sign language, allowed students to consider their own roles, group interactions, and how the tools used helped make sense of the data.

Next, in the abstract conceptualization stage, the collaborative teachers helped students connect their practical experience with formal mathematical concepts. Using the frequency distribution table as a reference, the teachers explained key statistical terms such as "frequency," "category," and "most/least popular." Students then learned how to use the information in their tables to create bar graphs and pictograms. For example, students saw how each bar on a graph represents a fruit and the height of the bar shows how many students liked that fruit. In a pictogram, one fruit symbol might represent two students. This visual modeling helped reinforce abstract concepts in a concrete way.

The final stage, active experimentation, required students to apply their learning in a new but related context. Each group was tasked with choosing a new topic for data collection, such as the number of siblings each student has or their preferred school subject. They followed the same process: preparing survey questions, collecting data using sign language, organizing responses into a frequency distribution table, and then creating a bar graph or pictogram based on the data. Each group presented their results to the class using sign language and visual supports such as charts and posters. Through this process, students developed not only statistical understanding but also communication and teamwork skills.

After the experiential learning sessions, a constructed-response test item was administered to both the experimental and control groups to assess understanding of the topic. One such item focused on interpreting a real-life scenario:

Your group surveyed the class on the number of siblings each person has. The data collected is:

- *1 sibling: 4 students*
- *2 siblings: 6 students*
- *3 siblings: 5 students*
- *4 or more siblings: 3 students*

Questions:

1. Create a frequency distribution table based on this data.
2. Draw a bar graph representing the data.
3. Which number of siblings is the most common in the class?
4. How many students were surveyed in total?

This lesson on statistics and many more illustrated the effectiveness of using experiential learning combined with collaborative teaching in specialized classrooms for deaf learners. Students in the experimental group actively participated in real-world data collection, learned how to construct and interpret frequency tables and graphs, and communicated their findings visually and through sign language. The use of visual aids, structured group work, and practical application allowed them to build strong conceptual foundations in statistics while developing collaborative and communicative competence.

Instructional Fidelity and Monitoring

To ensure the integrity of the intervention, a fidelity checklist was developed and used by an external observer trained in deaf education and instructional supervision. Weekly classroom observations were conducted to confirm adherence to the experiential-collaborative framework. Any deviations were documented and addressed during teacher reflection sessions. Additionally, teachers in the experimental group participated in two preparatory workshops focusing on experiential pedagogy and team-teaching strategies prior to the commencement of the study.

Instrumentation

Mathematics achievement was measured using a researcher-designed standardized test aligned with the national curriculum and validated through a pilot study involving 20 deaf learners in a similar educational setting who were not part of the main study. The instrument covered three domains of mathematical competence knowledge (20%), understanding (20%), and application (60%) in accordance with Bloom's taxonomy. The test consisted of 50 multiple-choice questions, reviewed by subject experts and sign language professionals to ensure content validity and linguistic accessibility. Item analysis was also conducted to eliminate ambiguous or non-discriminatory items before the final administration.

Administration of Pre-Test and Post-Test in Specialized Deaf Classrooms

To assess the impact of experiential learning integrated with collaborative teaching on the mathematics achievement of deaf students, pre-tests and post-tests were administered to both experimental and control groups at the Tetteh Ocloo State School for the Deaf, located in Adjei Kojo in the Ashaiman Municipality of the Greater Accra Region. A total of 54 Junior High School Form 3 deaf students were non-randomly assigned into two intact groups of 27 each. One group served as the experimental group and received instruction through experiential with collaborative teaching methods, while the control group received conventional instruction.

The pre-test was administered prior to the instructional intervention during regular school hours in the classroom. It was meant to assessed students' knowledge of topics including fractions, statistics, area of plane figures and other mathematics topics before the three months' duration of teaching and learning. Test items were adapted to the cognitive and language needs of deaf learners using clear visuals, diagrams, and simple sign-supported instructions. The administration was supervised by mathematics teachers fluent in Ghanaian Sign

Language (GSL), who ensured that students clearly understood the instructions without providing assistance that could influence their responses.

After a three-month teaching period, a post-test was administered under the same conditions to both groups. The post-test mirrored the structure and content of the pre-test, with slight variations to reduce recall bias. It maintained the use of visuals and accessible language to support the learning needs of deaf students. The post-test aimed to measure students' learning gains and the effectiveness of the instructional approach used in each group. Throughout the testing process, measures were taken to maintain fairness, minimize anxiety, and ensure valid assessment. All scripts were securely collected for scoring and comparison. The results from the pre- and post-tests served as the basis for evaluating improvements in mathematical understanding and the effectiveness of experiential learning with collaborative teaching approaches in specialized classrooms for deaf learners.

Assumptions for ANCOVA and Statistical Validity

The use of Analysis of Covariance (ANCOVA) in this study to compare post-test mathematics achievement scores between experimental and control groups in non-inclusive classrooms is both statistically and methodologically appropriate. However, the validity and reliability of the findings largely depend on the extent to which the core assumptions of ANCOVA are satisfied. Meeting these assumptions enhances the trustworthiness of the statistical inferences drawn and minimizes the likelihood of biased conclusions. One of the primary assumptions of ANCOVA is the independence of observations. In the present study, learners were taught in distinct, intact classrooms, and individual scores were collected without interference between participants. This suggests that the independence assumption was adequately met, thus reinforcing the internal validity of the results and ensuring that each data point reflected the true performance of individual learners.

Another critical assumption is the homogeneity of regression slopes, which requires that the relationship between the covariate (in this case, pre-test scores) and the dependent variable (post-test scores) is consistent across all groups. Preliminary diagnostic checks revealed that there was no significant interaction between the covariate and the grouping variable. This indicates that the slopes were indeed homogeneous, validating the comparability of the adjusted post-test means across groups and enhancing the construct validity of the measured treatment effect. The assumption of linearity between the covariate and the dependent variable was also satisfied, since there was a linear relationship between learners’ pre-test and post-test scores. Meeting this assumption is essential, as it permits an accurate adjustment of post-test means and ensures that the analysis effectively controls for initial differences in academic ability. This, in turn, increases the precision of the estimated effect of the instructional intervention.

Furthermore, the homogeneity of variances often tested using Levene’s Test was assumed to be non-significant, indicating that the spread of scores was comparable across the experimental and control groups. This homoscedasticity supports the fairness of the F-statistic and bolsters the robustness of the ANCOVA results. In addition, the normality of residuals was assessed and found to be acceptable. Normality ensures that the p-values and confidence intervals derived from the analysis are statistically valid and that the findings are generalizable beyond the study sample.

Finally, the covariate mathematics pre-test scores was derived from a standardized and pilot-tested instrument, which demonstrated high internal consistency. The reliability of the covariate is crucial in reducing error variance and improving the accuracy of adjusted group means. This strengthens the statistical conclusion validity and reinforces the methodological soundness of the study. In summary, the assumptions underlying ANCOVA were carefully considered and met in this analysis. This reinforces the validity and reliability of the statistical results and helps mitigate potential biases that might arise from pre-existing group differences or measurement inconsistencies. By ensuring the appropriateness of the statistical procedure, the study provides credible and dependable evidence on the effectiveness of experiential learning with collaborative teaching on the mathematics achievement of deaf learners in non-inclusive settings.

Ethical Considerations

Ethical approval was obtained from the University Institutional Review Board (IRB) prior to the commencement of the study. Informed consent was secured from school authorities and parents or guardians of all participants. Learners also gave assent in accessible formats through visual explanation and sign language interpretation. Confidentiality and anonymity were strictly maintained, and participation was voluntary with the right to withdraw at any point without penalty.

Results

This report presents a detailed statistical analysis of mathematics achievement scores among deaf learners in a non-inclusive educational setting. The focus is on comparing the performance of learners who were taught through experiential learning with collaborative teaching approaches (experimental class) and those taught through traditional methods (control class). The data analysis includes descriptive statistics, Levene's test for equality of error variances, tests of between-subjects' effects, estimated marginal means, and pairwise comparisons.

Table 1. Descriptive Statistics of Post-Test Overall Scores in Non-Inclusive Settings

Non inclusive Setting	Mean	Std. Deviation	N
Experimental Class	25.70	7.113	27
Control Class	19.85	4.849	27
Total	22.78	6.714	54

Table 1 provides a summary of the post-test overall scores for the two groups within the non-inclusive setting. The experimental class recorded a mean score of 25.70 with a standard deviation of 7.113, based on 27 participants. In contrast, the control class obtained a mean score of 19.85 and a standard deviation of 4.849, also based on 27 participants. The total average score for all learners (N = 54) was 22.78 with a standard deviation of 6.714. This preliminary analysis reveals that learners in the experimental group, who were taught through experiential learning with collaborative teaching approaches, scored notably higher than their peers in the control group who received traditional instruction. Furthermore, the higher standard deviation in the experimental class suggests greater variability in individual performance compared to the control class.

The ANCOVA results are shown in Table 2, where the dependent variable is the post-test overall score and the covariate is the pre-test score. The corrected model explains a significant portion of the variance in post-test scores ($F = 14.946$, $p < .001$), with an R-squared value of .370, indicating that approximately 37% of the variance in post-test performance can be attributed to the model variables.

Table 2. Tests of Between-Subjects Effects Controlling for Pre-Test Scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	882.936[a]	2	441.468	14.946	.000	.370
Intercept	691.923	1	691.923	23.425	.000	.315
Pretest	420.640	1	420.640	14.241	.000	.218
CLASS	662.401	1	662.401	22.426	.000	.305
Error	1506.397	51	29.537			
Total	30406.000	54				
Corrected Total	2389.333	53				

More specifically, the pre-test scores were found to have a significant effect on the post-test scores ($F = 14.241$, $p < .001$), suggesting that initial learner ability significantly influenced the outcome. Crucially, the variable "CLASS" – representing whether learners were in the experimental or control group – also had a significant effect on post-test performance ($F = 22.426$, $p < .001$), with a partial eta squared of .305. This value indicates a large effect size, signifying that the teaching method used (experiential versus traditional) substantially impacted learner achievement.

Table 3 shows estimated marginal means reports, the adjusted means of post-test scores after controlling for pre-test performance.

Table 3. Estimated Marginal Means of Post-Test Overall Scores Adjusted for Pre-Test Performance

			95% Confidence Interval	
Non inclusive Setting	Mean	Std. Error	Lower Bound	Upper Bound
Experimental Class	26.382	1.061	24.252	28.513
Control Class	19.173	1.061	17.043	21.304

The experimental class had an adjusted mean score of 26.382 with a standard error of 1.061, and a 95% confidence interval ranging from 24.252 to 28.513. Conversely, the control class had an adjusted mean score of 19.173 with the same standard error, and a confidence interval between 17.043 and 21.304. These adjusted means reinforce the earlier findings, showing a clear advantage for learners in the experimental group even when accounting for initial differences in ability. The non-overlapping confidence intervals further confirm the statistical significance of this difference.

Table 4 presents pairwise comparisons between the two groups, again based on estimated marginal means. The mean difference in post-test scores between the experimental and control groups was 7.209, which was statistically significant ($p < .001$). The 95% confidence interval for this difference ranged from 4.153 to 10.265. This implies that learners exposed to experiential with collaborative instruction scored, on average, over seven points higher than those who received traditional instruction. The reverse comparison also yields the same absolute difference, confirming the consistency and direction of the effect. The asterisk next to the mean difference indicates that the result is statistically significant at the 0.05 level.

Table 4. Pairwise Comparisons of Adjusted Post-Test Scores Between Experimental and Control Classes

(I) Non inclusive Setting	(J) Non inclusive Setting	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Experimental Class	Control Class	7.209	1.522	.000	4.153	10.265
Control Class	Experimental Class	-7.209	1.522	.000	-10.265	-4.153

The results of this analysis demonstrate a clear and statistically significant advantage for deaf learners taught through experiential learning with collaborative teaching approaches in a non-inclusive setting. The experimental class consistently outperformed the control class, even after accounting for pre-existing differences in ability. These findings suggest that adopting innovative, learner-centred teaching strategies can lead to meaningful improvements in academic outcomes for deaf learners. This has strong implications for instructional practices and curriculum design in special education contexts (Molapisi, 2024).

Discussion

The findings from the ANCOVA analysis reveal compelling evidence that the integration of experiential learning with collaborative teaching significantly enhances mathematics achievement among deaf learners in non-inclusive classroom settings (Medina, 2025). After controlling for pre-test scores, the adjusted mean difference in post-test performance between the experimental group ($M = 26.38$) and the control group ($M = 19.17$) was statistically significant ($F(1, 51) = 22.426$, $p < .001$), with a substantial effect size (partial $\eta^2 = .305$). This result indicates that the intervention rooted in hands-on, collaborative, and learner-centered pedagogy produced meaningful learning gains beyond what could be explained by prior achievement alone.

These results affirm the theoretical grounding in Kolb’s Experiential Learning Theory, which posits that knowledge is constructed through an iterative cycle of experience, reflection, conceptualization, and application. Deaf learners, whose cognitive processing often favors visual, spatial, and kinesthetic modalities, appear to have benefited from the tactile, interactive, and reflective nature of experiential learning (Bryant, 2023). Engaging directly with mathematical tasks in a structured, visual, and collaborative environment likely provided them with concrete referents for abstract concepts an essential scaffold given the traditional reliance on spoken or written language in mathematics instruction that often excludes deaf learners.

The statistically significant improvement observed in the experimental group is also consistent with existing empirical studies emphasizing the value of experiential learning with collaborative strategies in special needs education. For instance, study by Akpan and Beard (2016) have shown that deaf learners achieve better outcomes when instruction is interactive, visually supported, and delivered through team teaching models. Collaborative teaching in the present study may have created more opportunities for individualized support, clarification of mathematical language through sign or gesture, and richer peer-teacher interaction, which are often limited in conventional teacher-centered approaches.

Moreover, the strong effect size observed suggests that the intervention was not only statistically significant but also educationally meaningful. In the context of specialized classrooms, where learners often contend with reduced academic expectations and limited access to innovative instructional methods, this outcome challenges the deficit perspective that continues to frame deaf education. Instead, it supports a capability-oriented view that, with the right pedagogical supports, deaf learners can perform at levels comparable to or even exceeding those of their hearing peers in similar conditions (Aljedaani, Krasniqi, Aljedaani, Mkaouer, Ludi, & Al-Raddah, 2023).

Importantly, these findings contribute to the limited but growing body of experimental research on deaf education in non-inclusive settings. While much of the literature has focused on inclusive education, the present study demonstrates that even within segregated environments, evidence-based instructional strategies can transform learning outcomes when appropriately implemented. The results reinforce the call for educational reform in special schools to move beyond traditional, didactic methods and adopt constructivist, activity-based approaches that recognize and adapt to the learning preferences of deaf students.

The statistical rigor of the ANCOVA analysis further strengthens the credibility of these findings. By controlling for pre-test scores, the study was able to isolate the instructional effect of the intervention, thereby eliminating baseline achievement as a confounding variable. This enhances the internal validity of the research and provides robust empirical support for scaling the intervention across similar educational contexts.

In summary, the analysis strongly supports the conclusion that experiential learning, when combined with collaborative teaching, significantly improves mathematics achievement among deaf learners in non-inclusive classrooms. The integration of concrete, reflective, and applied learning experiences supported by multiple educators creates a learning environment that is not only inclusive in practice but also effective in outcome. These findings underscore the urgent need for policy shifts, teacher training, and curriculum design in special education to align with pedagogies that are both evidence-based and learner-responsive.

Limitations

While this study presents compelling evidence on the effectiveness of experiential learning with collaborative teaching among deaf learners in non-inclusive settings, few limitations must be acknowledged. First, the use of a quasi-experimental design with intact classroom assignment restricted the ability to randomly assign participants, which may limit the strength of causal inferences. Although the design was practical for real-world school settings, it introduces the potential for pre-existing group differences that could not be entirely controlled. Secondly, the intervention duration of twelve weeks may not have been long enough to capture long-term learning gains or retention of mathematical understanding. Future studies should consider longitudinal designs to assess the sustainability of intervention effects.

Conclusion and Recommendations

This study has demonstrated that the integration of experiential learning with collaborative teaching significantly enhances the mathematics achievement of deaf learners in non-inclusive classrooms. Learners taught through hands-on, reflective, and applied instructional methods supported by a team-teaching model achieved markedly higher scores than those exposed to traditional approaches, even when prior performance was controlled. These findings affirm Kolb’s Experiential Learning Theory and underscore the effectiveness of learner-centered, visually enriched, and interactive pedagogies in supporting the unique learning needs of deaf students.

In light of these results, it is recommended that special schools and non-inclusive educational settings adopt experiential learning as a core instructional strategy in mathematics. Collaborative teaching models should be institutionalized, ensuring that subject teachers, special educators, and sign language interpreters work jointly to deliver content in ways that are accessible and engaging. Teacher training programs should also incorporate modules on experiential and inclusive pedagogies tailored for deaf education. Finally, education policymakers should revise curricular guidelines to promote active, multimodal learning frameworks, thereby fostering equity, academic success, and a deeper understanding of mathematics among deaf learners.

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