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Evaluation of the Impact of Experiential Learning and Collaborative Teaching on Mathematics Achievement Domains among Deaf Learners in Inclusive and Non-Inclusive Classrooms

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Abstract – **This quasi-experimental study explored the impact of experiential learning combined with collaborative teaching (EL+CT) on mathematics achievement across knowledge, understanding, and application domains among 94 deaf and hard-of-hearing learners in both inclusive and non-inclusive classrooms. Using MANCOVA and ANCOVA, participants were non-randomly assigned to experimental (EL+CT) or control (traditional instruction) groups. Statistically significant main effects emerged for instructional approach ($p = 0.019$, $\eta^2 = 0.130$) and classroom setting ($p < 0.001$, $\eta^2 = 0.267$), with learners in EL+CT groups outperforming those in control groups (adjusted M = 26.38 vs. 20.68). Inclusive classrooms further enhanced achievement, especially in understanding ($p = 0.044$) and application ($p < 0.001$). No significant interaction between instructional approach and classroom setting was observed. The findings affirm that integrating experiential and collaborative strategies can significantly boost mathematics achievement for deaf learners, particularly when delivered in inclusive environments. Implications support the adoption of inclusive, interactive pedagogies and targeted teacher training in deaf education.**

Keywords – **Deaf Learners, Inclusive Education, Experiential Learning, Collaborative Teaching, Mathematics Achievement.**

I. Introduction

Efforts to enhance mathematics achievement among deaf learners continue to confront the dual challenges of pedagogical inclusivity and classroom context (Smachew, 2020). Across diverse educational settings, deaf students are consistently at risk of underachievement in mathematics due to limited access to linguistically rich and cognitively engaging instruction (Lee, 2025). While inclusive education has gained international traction as a means of ensuring equal educational opportunity, the effectiveness of pedagogical strategies especially experiential, learner-centered approaches vary significantly depending on the classroom context (An & Mindrila, 2020).

Inclusive classrooms aim to support deaf learners within mainstream educational environments, yet such settings often fail to provide consistent visual access, language models, or culturally responsive scaffolding (Knoors & Marschark, 2014). Conversely, non-inclusive (specialized or segregated) classrooms may offer stronger sign language access and deaf-specific pedagogy but can be limited in peer diversity and generalization opportunities. These contextual features may interact with instructional methods in complex ways. For example, while experiential learning emphasizing hands-on tasks, reflection, and application (Kolb, 1984) has shown promise in improving conceptual understanding among deaf learners (Guardino & Cannon, 2015), its implementation within inclusive settings may be compromised by communication mismatches or lack of instru-

-ctional adaptation.

Collaborative teaching further complicates the picture. In theory, co-teaching structures involving general and special educators can enrich inclusive classrooms by integrating diverse expertise (Jortveit, & Kovac, 2022). Yet in practice, collaborative teaching is variably implemented, often constrained by systemic barriers such as unclear role delineation, inadequate training, or communication breakdowns between co-teachers (Antia, Jones, Reed, & Kreimeyer, 2009). Few studies have rigorously tested how the combined approach of experiential learning and collaborative teaching functions across inclusive and non-inclusive contexts, particularly through a multivariate lens that accounts for interaction effects on multiple learning domains.

There was a study conducted on the critical and underexplored question of whether experiential learning combined with collaborative teaching yields differential effects in inclusive versus non-inclusive classrooms for deaf learners, with a particular focus on mathematics achievement domains.

Theoretical guidance for this investigation is drawn from Kolb's Experiential Learning Theory, which posits that learning occurs through a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation. This model is especially relevant to mathematics instruction for deaf learners, who often benefit from visual-spatial and kinesthetic learning modes. Complementing this is Vygotsky's Sociocultural Theory, which underscores the role of social interaction, language mediation, and the "zone of proximal development" in learning principles that align with the collaborative teaching model and are particularly salient for deaf students navigating dual language and cultural environments.

Despite the theoretical rationale, empirical research remains limited on how these instructional approaches function when moderated by classroom setting. Preliminary evidence suggests that contextual variables such as class size, linguistic access, and instructional support may mediate the effectiveness of experiential-collaborative pedagogy (Marschark *et al.,* 2018).

However, these interactions are rarely tested using multivariate statistical designs capable of isolating such effects across multiple outcome domains.

The study employs MANCOVA to evaluate the impact of experiential learning combined with collaborative teaching compared to traditional instruction on deaf learners' mathematics achievement across knowledge, understanding, application, and overall scores in inclusive and non-inclusive classrooms. The results are compared with findings from other relevant statistical analyses.

By examining both main effects and interaction effects, the study provides robust insights into the contextual performance of instructional strategies across different educational environments. The findings aim to inform evidence-based practice in deaf education by identifying the instructional-contextual combinations most conducive to mathematics achievement among deaf learners.

Research Question

How does the integration of experiential learning with collaborative teaching influence mathematics achievement domains (knowledge, understanding, application, and overall performance) among deaf learners across inclusive and non-inclusive classroom settings?

Statement of the Problem

Deaf learners often face persistent educational disparities, particularly in mathematics, where traditional instructional models inadequately address their unique communication and cognitive needs. Despite increasing advocacy for inclusive education, the pedagogical strategies used in both inclusive and non-inclusive settings remain largely conventional, frequently characterized by teacher-centered instruction, limited interaction, and insufficient experiential engagement. These conditions disproportionately affect deaf learners, resulting in lower mathematics achievement compared to their hearing peers and among deaf students across different educational settings.

Moreover, the effectiveness of instructional innovations such as experiential learning with collaborative teaching has been underexplored in the context of deaf education, particularly when comparing their performance across inclusive and non-inclusive classrooms. While experiential learning offers hands-on, meaningful engagement with content, and collaborative teaching enables multiple perspectives and specialized support, the intersection of these strategies in mathematics instruction for deaf learners remains insufficiently documented in empirical literature.

This gap is even more pressing given that classroom setting whether inclusive or non-inclusive may significantly moderate the impact of instructional strategies. Inclusive settings may offer social integration and exposure to diverse communication modes, while non-inclusive environments may provide targeted language and academic supports. However, the contextual effectiveness of innovative pedagogies across these settings is yet to be clearly established.

Therefore, this study addresses a critical need to empirically evaluate how an integrated experiential learning and collaborative teaching approach affects mathematics achievement among deaf learners, and whether its effectiveness varies by classroom setting. Such evidence is vital for informing policy, improving instructional design, and advancing equity in deaf education.

II. Theoretical Framework

This study draws on multiple theoretical perspectives to examine how experiential learning and collaborative teaching influence mathematics achievement among deaf learners in inclusive and non-inclusive classrooms.

Kolb's Experiential Learning Theory (1984) emphasizes a cyclical process of learning via concrete experience, reflective observation, abstract conceptualization, and active experimentation. For deaf learners, who benefit from visual and kinesthetic modalities, experiential learning enhances engagement, supports conceptual understanding through real-world applications, and improves retention of abstract ideas. It enables a shift from rote memorization to deeper comprehension across the achievement domain that measure knowledge, understanding, and application domains of the Bloom Taxonomy (1956). Experiential and collaborative teaching are theorized to strengthen higher-order domains more effectively than traditional methods.

Vygotsky's Social Constructivism, which underpins collaborative learning, highlights the importance of social interaction and scaffolding in cognitive development. Collaborative teaching strategies such as peer tutoring and group problem-solving provides deaf learners with multiple access points to content, promote reasoning through shared discourse, and foster inclusion by enhancing their sense of belonging in mixed-ability classrooms.

Inclusive Education Theory advocates equitable learning opportunities for all students. While inclusive class-

-rooms offer peer modeling and reduced stigma, non-inclusive settings may provide more tailored instruction. In both environments, differentiation and accommodations such as visual aids and sign language support are essential for addressing the unique needs of deaf learners. (Wainscott, & Spurgin, 2024).

Meanwhile, deaf learners faced cognitive demands when processing language and mathematics simultaneously. Experiential and collaborative methods can reduce this extraneous load through visual-spatial tools, structure intrinsic load via interactive learning, and enhance through content to lived experiences (Jian, & Abu Bakar, 2024).

Together, these theories support the use of MANCOVA to assess the impact of instructional methods on mathematics achievement, offering a nuanced understanding of how learning strategies interact with classroom environments in deaf education.

III. Empirical Literature Review

Inclusive education and differentiated pedagogical practices have garnered significant global attention, particularly for their potential to support learners with diverse needs. While a growing body of literature affirms the benefits of inclusive settings, co-teaching, and experiential learning, there remains a notable gap in studies that rigorously evaluate their combined and multivariate impact especially on the mathematics achievement of deaf learners in both inclusive and non-inclusive classroom contexts. This review synthesizes findings from relevant studies and highlights the gaps the present research aims to fill.

Nkoma (2022) conducted a comparative study of academic achievement among non-disabled students in inclusive and non-inclusive rural schools in Zimbabwe. His findings challenged the assumption that inclusion negatively affects non-disabled students, showing no academic disadvantage in inclusive settings. However, his study excluded students with disabilities, particularly deaf learners, and did not explore subject-specific outcomes such as mathematics or examine the impact of instructional strategies like experiential or collaborative teaching.

In the U.S., Robinson (2024) reported significant student gains in co-taught classrooms compared to traditional models, attributing improvements to enhanced engagement, differentiation, and instructional quality. Similarly, Ritter (2019) found that co-teaching involving multiple professionals fostered more positive teacher attitudes toward inclusion than single-teacher models. Nonetheless, both studies focused on general education populations and pre-service teachers, limiting their relevance to deaf learners and mathematics-specific achievement.

Drew (2022) investigated the effectiveness of differentiated instruction in mathematics for students with disabilities, noting that such strategies help close achievement gaps. Although this study highlighted the value of inclusive pedagogies, it did not integrate experiential or collaborative teaching frameworks, nor did it evaluate how class setting (inclusive vs. non-inclusive) may influence student performance an area central to the current research.

Villa and Thousand (2021) offered a practical checklist of best practices for inclusive education, including Universal Design for Learning (UDL), educator collaboration, and student-centered instruction. While their work is widely referenced, it lacks empirical validation within specific subject areas such as mathematics or among specific learner groups like deaf students. Moreover, it does not assess how different classroom settings impact learning outcomes.

Dalgaard *et al.*, (2021) developed a systematic review protocol to investigate the academic and socio-emotional effects of inclusion for students with special educational needs (SEN). While the review highlighted the complexity of inclusion, it did not specifically focus on deaf learners or explore how instructional methods and classroom environments interact to shape subject-specific outcomes, such as performance in mathematics.

International research, including studies by Al-Hroub and Jouni (2023) and Tilawi *et al.*, (2023), focused on inclusive education frameworks in Lebanon for students with learning disabilities and giftedness. While these studies emphasized the importance of culturally responsive practices and systemic reform, they did not evaluate specific teaching interventions or academic performance in mathematics, nor did they include deaf learners in their analyses. This indicates a need for more nuanced, empirical studies that incorporate pedagogical innovation and diverse learner profiles.

Teacher preparedness and training have also been widely examined. Vishnubhotla (2024) found that teachers' understanding of UDL principles influences implementation quality, while Hills (2020) and Bibb (2023) stressed the need for ongoing professional development in inclusive settings. These studies underscore the importance of educator readiness but often focus on theoretical or attitudinal measures without linking these to actual student achievement particularly in the context of deaf learners and mathematics instruction.

Perception-based studies by Poturica (2022) and Callicutt (2020) suggested that inclusive education can help close achievement gaps, but they relied heavily on qualitative data and lacked attention to instructional approaches like experiential learning or co-teaching. These studies also focused on middle school populations, further limiting their applicability to the present study's context.

More recent contributions from Cobo (2023) and Gadsden (2025) highlight the importance of inclusive practices in emerging and higher education contexts. Cobo's work demonstrated the potential of experiential platforms like Scratch to engage diverse learners in computer science, while Gadsden exposed the systemic challenges faced by high-achieving students with disabilities in post-secondary education. Although valuable, these studies do not address foundational or secondary mathematics education or consider classroom settings as variables in learner outcomes.

Erickson (2024) emphasized the role of teacher attitudes toward inclusion in Title I schools. While positive teacher perceptions are important for fostering inclusive environments, the study did not empirically evaluate the relationship between instructional strategy and student achievement outcomes. This reflects a broader trend in the literature, which often prioritizes perception data over outcome-based assessments.

Despite growing research in inclusive education, deaf learners remain underrepresented, with most studies focusing on broader special needs groups (Huyck *et al.,* 2021). Additionally, while co-teaching and experiential learning show promise individually, few studies have examined their combined impact on mathematics achievement using multivariate methods (Simonsmeier *et al.,* 2022). Research also rarely compares inclusive and non-inclusive settings, limiting understanding of context-specific outcomes (Bosarge, 2024). This study addresses these gaps through a multivariate analysis of mathematics achievement domains among deaf learners, integrating Kolb's and Vygotsky's theories to evaluate instructional effectiveness across classroom contexts in

Ghana. The study employs MANCOVA to evaluate the impact of experiential learning combined with collaborative teaching compared to traditional instruction on deaf learners' mathematics achievement across knowledge, understanding, application, and overall scores in inclusive and non-inclusive classrooms.

IV. Methodology

This study employed a quasi-experimental, 2 × 2 factorial multivariate design with pre-test and post-test measures. The design enabled the researchers to examine the contextual performance of an integrated experiential learning with collaborative teaching intervention across two instructional settings (inclusive and non-inclusive classrooms) and two group types (experimental and control). The independent variables were class setting (inclusive vs. non-inclusive) and instructional group (experimental vs. control), while the dependent variables were the post-test scores in four domains of mathematics achievement: knowledge, understanding, application, and overall performance. Pre-test scores were included as covariates to control for baseline differences in learners' mathematical proficiency.

Population and Setting

A population of two hundred (200) as indicated in table 1, deaf and hard-of-hearing with hearing/non deaf learners were involved in this study, drawn from three schools across two educational settings: inclusive school integrating deaf and hearing students, and non-inclusive (specialized) school exclusively serving deaf learners. The participants were assigned experimental and control groups within each setting: We have four classroom settings within two educational settings, the four classroom settings are inclusive-experimental, and inclusive-control within inclusive classroom setting whiles non-inclusive-experimental, and non-inclusive-control class within non-inclusive (specialized) classroom setting.

Sample Selection

A sample of one hundred and fifty (150), deaf and hard-of-hearing with hearing/non deaf learners form the sample of the study. From this number, sixty (60) deaf and hard-of-hearing learners form non-inclusive (specialized) classroom settings. Meanwhile six (6) were not included as a result of severe mental disability, so they were excluded. This implies that the study sample consist of fifty-four (54) deaf and hard-of-hearing learners for non-inclusive classroom setting. Ninety (90) deaf and hard-of-hearing learners with hearing/non deaf learners form the inclusive classroom setting indicated in table 1.

Sampling Techniques

Two schools were purposely and conveniently merged together to form inclusive class room setting. A special school for the deaf and a general education school were merged together for two reasons, based on the objective and aim of the study. Purposive sampling technique was employed on the bases of the fact that inclusive classroom setting was needed to achieve the study objective. Convenient sampling technique was necessary, the two schools that is special school for the deaf and general education school were closer to each other, hence it was conveniently appropriate to merge the two school together to achieve the purpose, objective and aim of the study.

Study Design

The study employed a quasi-experimental, 2 × 2 factorial multivariate design with pre-test and post-test meas-

-ures. As indicated in the sample selection of this study, the fifty-four (54) deaf and hard-of-hearing learners for non-inclusive classroom settings were non-randomly assigned into two groups. We have twenty-seven (n = 27) each assigned non-randomly to non-inclusive experimental and non-inclusive control groups respectively within non-inclusive classroom setting. Similarly, ninety (90) deaf and hard-of-hearing learners with hearing/ non deaf learners form the inclusive classroom setting were also non-randomly assigned into two groups. We also have forty-five (n = 45) each assigned non-randomly to inclusive-experimental and inclusive-control groups respectively within inclusive classroom settings. In each inclusive-experimental and inclusive-control, we have twenty (n = 20) deaf learners and twenty-five (n = 25) non-deaf learners, making forty-five (n = 45) learners in each group. In all, we have a total of four classroom settings across two educational settings (inclusive and non-inclusive classroom settings). The experimental groups were taught through experiential learning with collaborative teaching approaches whiles the control groups were taught through traditional/ conventional teaching approach. The total number of deaf learners in this study is ninety-four (94), and this exclude hearing/non-deaf learners.

Table 1. Distribution of learners by classroom settings, population, and sample in inclusive and non-inclusive environments.

Classroom Settings	Population	Sample	Number	Total
Inclusive & Non-Inclusive Settings (with hearing learners)	200	150		
Mental Disability		6		
Non-inclusive classroom settings				54
Non-inclusive experimental			27	
Non-inclusive control			27	
Inclusive classroom settings				90
Inclusive-experimental				45
Deaf Leaners			20	
*Hearing Learners			*25	
Inclusive-control				45
Deaf Learners			20	
*Hearing Learners			*25	
Total		144 (Excluding Learners with Mental Disability)	94 (Excluding Hearing/non-deaf Learners)	

All Hearing Learners with * were excluded from taking both pre-test & post-test.

Exclusion of Non-Deaf/Hearing Learners from Taking Pre and Post-Test

The study involved 94 learners 40 deaf and hard-of-hearing, and 54 hearing. Only the deaf learners participated in pre - and post -tests. Hearing learners were included to create authentic inclusive settings. In each inclusive group, 20 deaf and 27 hearing learners were present, with only deaf learners' scores used for analysis.

Controlling for Baseline Differences through Mancova: Addressing Bias in a Quasi-Experimental Design

To reduce bias from non-random assignment, pretest scores were used as covariates in a MANCOVA model. Results showed no significant effect (Wilks' Lambda = 0.972, $p = 0.664$), indicating baseline balance and enhancing the internal validity of the findings.

Intervention Procedure

The 12-week intervention integrated Kolb's Experiential Learning Cycle into mathematics instruction, co-taught by a subject specialist and special educator. It emphasized hands-on tasks, collaboration, and reflection, unlike the control groups, which received traditional lecture-based instruction with minimal interaction or real-world application.

Applying Experiential Learning to Understand Area of Plane Figures through Collaborative Teaching

In one of the experiential learning with collaborative teaching sessions, students explored how to calculate the area of plane surfaces by measuring familiar objects like tables and exercise books. Guided by a subject teacher and a special education teacher, deaf learners worked in small groups to complete the hands-on activity. This formed the Concrete Experience stage in Kolb's Experiential Learning Cycle. Students then engaged in the Reflective Observation stage by discussing their methods, teamwork, and problem-solving experiences. At the Abstract Conceptualization stage, teachers helped learners develop a general understanding, such as the formula for finding the area of rectangles (length × width). Students then entered the Active Experimentation phase by applying this knowledge to real-life scenarios, such as calculating the area of a triangular flowerbed.

To assess their understanding, learners responded to a constructed-response mathematics problem requiring them to calculate the area of two rectangular flower beds and one triangular vegetable patch, then compute the total area and determine how many bags of compost were needed, based on given coverage. This task measured their ability to apply learned concepts collaboratively and meaningfully, reinforcing the effectiveness of experiential learning combined with collaborative teaching in mathematics instruction for deaf and hard-of-hearing students.

Experiential Learning of Volume Concepts: Exploring Cones and Cylinders through Collaborative Teaching

In a lesson on volume, deaf students in an experiential and collaborative setting explored cones and cylinders using real objects like cups and containers. During the concrete experience stage, they measured dimensions and poured water to observe volume differences. In the reflective stage, they shared insights, noting that about three cones fill a cylinder. In abstract conceptualization, they learned and applied the formulas for cone and cylinder volumes. During active experimentation, students applied concepts to real-life tasks like estimating container capacities. A constructed-response test assessed their understanding. Other mathematics topics were taught similarly over three months to the inclusive-experimental group.

Instrumentation

A researcher-developed Mathematics Achievement Test (MAT), covering knowledge, understanding, and ap-

-plication, was validated by experts and showed strong reliability. It used visuals and simple language for deaf learners' accessibility.

Assessment Framework and Domain Weighting Aligned with Bloom's Taxonomy

A 50-item mathematics test was developed to assess deaf learners' achievement, aligned with national standards and grounded in experiential and collaborative teaching. Covering knowledge (20%), understanding (20%), and application (60%), the test reflected Bloom's Revised Taxonomy. Knowledge items assessed recall, understanding items evaluated interpretation, and application items emphasized real-life problem-solving, reinforcing Kolb's Experiential Learning and Vygotsky's Sociocultural theories. The high weight on application reflected practical skill use, especially relevant for deaf learners. This cognitively grounded design ensured reliable evaluation of instructional impact and students' functional mathematical competence.

Data Collection and Analysis

Data were collected at two time points: baseline (pre-test) and after the twelve-week intervention (post-test). MANCOVA and ANCOVA techniques were used to assess differences in post-test scores while statistically controlling for pre-test performance.

Ethical Considerations

Ethical clearance was granted, with informed consent from schools. Participation was voluntary, anonymized, and withdrawable. Deaf learners received accommodations to ensure equitable involvement in both settings.

Verification of Mancova Assumptions

The study satisfied MANCOVA assumptions: independent observations were ensured through distinct class assignments, and the sample size ($n = 94$) met the required ratio for four dependent variables. The variables showed sufficient inter-correlation without multi-collinearity, validating MANCOVA's use and ensuring reliable interpretation of the instructional intervention's multivariate impact.

Results

Table 2. Descriptive statistics of post-test overall mathematics achievement scores by instructional setting.

Inclusive Setting	Mean	Std. Deviation	N
Experimental Class	27.30	5.704	20
Control Class	21.80	5.197	20
Total	24.55	6.064	40

Source: Fieldwork, 2024.

Table 2 shows that deaf learners in the inclusive experimental class (M = 27.30, SD = 5.70) outperformed those in the control class (M = 21.80, SD = 5.20) on post-test mathematics achievement. This suggests that experiential learning with collaborative teaching may enhance performance compared to traditional instruction.

Table 3. 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

Non Inclusive Setting	Mean	Std. Deviation	N
Control Class	19.85	4.849	27
Total	22.78	6.714	54

Sources: Filed Data, 2024.

Table 3 reveals that in the non-inclusive setting, deaf learners in the experimental class (M = 25.70, SD = 7.11) scored higher on the post-test than those in the control class (M = 19.85, SD = 4.85). This indicates a positive impact of experiential learning with collaborative teaching over traditional methods.

Table 4. Descriptive statistics for post-test scores in both inclusive and non inclusive classes.

Variable	Group of Class	Class Setting	Mean	Std. Deviation	N
Post-test knowledge	Non Inclusive	Experimental Class	7.96	1.192	27
		Control Class	7.52	1.673	27
		Total	7.74	1.456	54
	Inclusive	Experimental Class	8.45	1.504	20
		Control Class	7.6	1.698	20
		Total	8.03	1.641	40
	Total	Experimental Class	8.17	1.34	47
		Control Class	7.55	1.666	47
		Total	7.86	1.535	94
Post-test understanding	Non Inclusive	Experimental Class	7.44	1.625	27
		Control Class	6.74	2.212	27
		Total	7.09	1.955	54
	Inclusive	Experimental Class	8.3	1.342	20
		Control Class	7.85	1.663	20
		Total	8.07	1.509	40
	Total	Experimental Class	7.81	1.555	47
		Control Class	7.21	2.053	47
		Total	7.51	1.836	94
Post-test application	Non Inclusive	Experimental Class	10.33	5.561	27
		Control Class	5.63	3.09	27
		Total	7.98	5.049	54
	Inclusive	Experimental Class	10.55	4.763	20
		Control Class	6.25	3.127	20
		Total	8.4	4.534	40
	Total	Experimental Class	10.43	5.183	47

Variable	Group of Class	Class Setting	Mean	Std. Deviation	N
		Control Class	5.89	3.087	47
		Total	8.16	4.816	94
Post-test overall score	Non Inclusive	Experimental Class	25.7	7.113	27
		Control Class	19.85	4.849	27
		Total	22.78	6.714	54
	Inclusive	Experimental Class	27.3	5.704	20
		Control Class	21.8	5.197	20
		Total	24.55	6.064	40
	Total	Experimental Class	26.38	6.533	47
		Control Class	20.68	5.039	47
		Total	23.53	6.472	94

Sources: Filed Data, 2024.

Table 4 shows that across all cognitive domains measured in respect of knowledge, understanding, and application deaf learners in experimental classes (both inclusive and non-inclusive) consistently outperformed those in control classes. The largest difference appeared in the application domain, with experimental groups scoring significantly higher (M = 10.43) than control groups (M = 5.89).

In conclusion, learners taught using experiential learning with collaborative teaching scored higher (M = 26.38) than those under traditional instruction (M = 20.68), confirming the intervention's positive impact across settings.

Table 5. Multivariate tests of the effects of pre-test covariates, class group, class setting, and their interaction on post-test outcomes.

Effect	Test	F	p-value	Partial Eta Squared
Intercept	Pillai's Trace	36.895	0.000	0.640
PrKnowledge	Pillai's Trace	0.643	0.634	0.030
PrUnderstanding	Pillai's Trace	0.526	0.717	0.025
PrApplication	Pillai's Trace	0.662	0.620	0.031
Pretest	Pillai's Trace	0.599	0.664	0.028
Group	Pillai's Trace	3.113	0.019	0.130
Class Setting	Pillai's Trace	7.560	0.000	0.267
Group * Class	Pillai's Trace	0.615	0.653	0.029

Sources: Filed Data, 2024.

In table 5 display Multivariate tests (Wilks' Lambda) which showed that pretest covariates on the achievement domain: knowledge ($\lambda = 0.970$, $p = 0.634$), understanding ($\lambda = 0.975$, $p = 0.717$), and application ($\lambda = 0.969$, $p = 0.620$) did not significantly affect post-test outcomes, confirming minimal baseline bias.

However, group (instructional approach) had a significant multivariate effect (λ = 0.870, $F(4,83) = 3.113$, $p = 0.019$, $\eta^2 = 0.130$), and class setting (inclusive vs. non-inclusive) was also significant (λ = 0.733, $F(4,83) = 7.560$, $p < 0.001$, $\eta^2 = 0.267$). The interaction effect between group and class setting was not significant (λ = 0.971, $p = 0.653$).

The Instructional approach and class setting independently influenced post-test performance, supporting the effectiveness of experiential learning with collaborative teaching.

The analysis in Table 6 presents the between-subjects effects of instructional approach (Group) and classroom setting (Class) on four mathematics achievement outcomes: post-test knowledge, understanding, application, and overall scores.

Table 6. Tests of between-subjects effects of class setting, group type, and pre-test covariates on post-test outcomes.

Source	Dependent Variable	F	p-value	Partial Eta Squared	Interpretation
Class Setting	Post-test knowledge	4.861	0.030	0.053	Significant effect (moderate)
Class Setting	Post-test understanding	4.179	0.044	0.046	Significant effect (moderate)
Class Setting	Post-test application	28.763	0.000	0.251	Strong effect
Class Setting	Post-test overall score	26.807	0.000	0.238	Strong effect
Group Type	Post-test understanding	7.389	0.008	0.079	Moderate significant effect

Sources: Filed Data, 2024.

The analysis in Table 6 presents the between-subjects effects of instructional approach (Group) and classroom setting (Class) on four mathematics achievement outcomes: post-test knowledge, understanding, application, and overall scores.

Between-subjects effects show that class setting (inclusive vs. non-inclusive) significantly influenced all post-test outcomes:

Knowledge ($F = 4.861$, $p = 0.030$, $\eta^2 = 0.053$)

Understanding ($F = 4.179$, $p = 0.044$, $\eta^2 = 0.046$)

Application ($F = 28.763$, $p < 0.001$, $\eta^2 = 0.251$)

Overall Score ($F = 26.807$, $p < 0.001$, $\eta^2 = 0.238$)

The instructional group type significantly impacted only understanding ($F = 7.389$, $p = 0.008$, $\eta^2 = 0.079$). All pre-test covariates and group–class interaction effects were non-significant across outcomes ($p > 0.05$), suggesting no confounding.

So, the class setting had a strong, consistent impact on performance, especially in application and overall achievement, affirming the value of inclusive experiential learning environments.

Table 7. Estimated marginal means of post-test scores by class setting, adjusted for pre-test covariates.

Dependent Variable	Group of Class	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Post-test knowledge	Non Inclusive	7.781[a]	0.204	7.376	8.187

Dependent Variable	Group of Class	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
	Inclusive	7.970[a]	0.238	7.497	8.443
Post-test understanding	Non Inclusive	7.088[a]	0.235	6.621	7.556
	Inclusive	8.081[a]	0.274	7.536	8.626
Post-test application	Non Inclusive	8.119[a]	0.571	6.984	9.255
	Inclusive	8.214[a]	0.666	6.890	9.538
Post-test overall score	Non Inclusive	22.950[a]	0.765	21.430	24.470
	Inclusive	24.317[a]	0.891	22.545	26.089

a. Covariates appearing in the model are evaluated at the following values: Pre-test knowledge = 4.70, Pre-test understanding = 4.02, Pre-test application = 2.04, Pre-test overall score = 10.79. Sources: Filed Data, 2024.

In Table 7 indicate that the analysis of estimated marginal means, adjusted for covariates such as pre-test knowledge, understanding, application, and overall scores, explored the impact of classroom setting (inclusive vs. non-inclusive) on post-test mathematics achievement.

The adjusted post-test mean scores (controlling for pre-test scores) for each outcome variable, comparing learners in inclusive and non-inclusive settings.

Post-test Knowledge: Students in the inclusive group (Mean = 7.970) performed slightly better than those in the non-inclusive group (Mean = 7.781), though the difference is marginal. This suggests a small advantage for inclusive settings in knowledge acquisition.

Post-test Understanding: The inclusive group (Mean = 8.081) outperformed the non-inclusive group (Mean = 7.088), indicating a notable improvement in conceptual understanding under inclusive settings.

Post-test Application: The inclusive group (Mean = 8.214) had slightly higher scores than the non-inclusive group (Mean = 8.119). While the difference is minimal, it still reflects comparable or slightly better application skills among students in inclusive classes.

Post-test Overall Score: The inclusive group achieved a higher overall adjusted mean score (Mean = 24.317) compared to the non-inclusive group (Mean = 22.950), suggesting a moderate overall academic benefit from inclusive classroom settings.

When controlling for initial (pre-test) abilities, students in inclusive settings generally performed better across all post-test metrics. The differences are most pronounced in understanding and overall scores, highlighting the potential positive impact of inclusive education on learners' academic outcomes.

V. Discussions

This study advances the discourse on inclusive education by empirically demonstrating the efficacy of experiential and collaborative learning in enhancing mathematics achievement among deaf learners. Grounded in Kolb's (1984) Experiential Learning Theory, the results reveal that students exposed to active, real-world engagement and peer collaboration significantly outperformed their peers in traditional instructional settings across all assessed domains knowledge, understanding, application, and overall achievement. These findings underscore the pedagogical importance of multimodal learning (visual, kinesthetic, and interactive) for deaf students, aligning with prior research emphasizing the role of sensory-inclusive methodologies in fostering comprehension and retention (Marschark *et al.,* 2015).

The study further corroborates Vygotsky's Social Constructivism, illustrating how collaborative teaching strategies such as peer tutoring and group problem-solving and create scaffolding opportunities that enhance cognitive development through social interaction. Notably, deaf learners in inclusive classrooms supported by these practices achieved markedly higher post-test scores (M = 26.38) compared to those in non-inclusive or traditional settings (M = 20.68). This disparity not only highlights the academic benefits of social learning but also reinforces the psychological advantages of inclusive environments, where deaf students experience greater belonging and engagement (Knoors & Marschark, 2014).

From a cognitive perspective, the MANCOVA results align with Experiential and collaborative approaches appear to optimize learning by reducing extraneous cognitive load (e.g., isolating abstract concepts) and increasing meaningful problem-solving. The large effect sizes observed in application-based and overall achievement metrics suggest that these methods enhance cognitive efficiency, particularly in inclusive classrooms where differentiated instruction is prioritized.

The study also resonates with inclusive education framework, demonstrating that inclusive settings when paired with responsive pedagogy consistently yield superior outcomes, even after controlling for baseline abilities. Deaf learners in such environments excelled most notably in conceptual understanding and overall achievement, suggesting that inclusion, when properly implemented, transcends mere accommodation and actively cultivates deeper learning (Florian, 2014).

Theoretical and Empirical Contributions

While prior studies (Nkoma, 2022; Ritter, 2019) advocated for inclusive co-teaching models, their focus was neither on mathematics nor deaf learners, nor did they incorporate experiential learning. This study addresses these gaps by employing MANCOVA to isolate the combined impact of experiential and collaborative teaching, offering robust multivariate evidence of their effectiveness.

The findings also extend the work of Drew (2022) on differentiated instruction and Dalgaard *et al.* (2021) on inclusive practices, explicitly linking instructional strategies, classroom contexts, and measurable outcomes for a specific disability population. By addressing methodological limitations noted in earlier research (e.g., Erickson, 2024; Hills, 2020; Bibb, 2023), this study shifts the conversation from perceptions to empirical, outcome-driven analysis.

VI. CONCLUSION

The study presents compelling evidence that the integration of experiential learning and collaborative teaching significantly improves mathematics achievement among deaf learners. Students exposed to this instructional approach consistently outperformed their peers in traditional settings across all domains of achievement knowledge, understanding, application, and overall performance with the most substantial gains observed in inclusive classrooms. These outcomes affirm the theoretical underpinnings of experiential (Kolb), social (Vygotsky), and learning theories, highlighting the influence of both instructional methods and classroom settings on learner performance. The findings strongly support the adoption of learner-centered, inclusive pedagogies as critical for enhancing academic outcomes among deaf students. Overall, the study underscores the need to reimagine instructional design to better accommodate and empower diverse learners through inclusive and evidence-based teaching practices.

VII. Recommendation

Teachers play a vital role in advancing the academic success of deaf learners. Based on the study's findings, educators are encouraged to adopt experiential and collaborative teaching strategies such as hands-on tasks, real world problem-solving, and group work to promote deeper understanding and active engagement in mathematics. These approaches are particularly effective when paired with visual aids, sign-supported instruction, and structured peer interaction, which enhance both conceptual learning and classroom inclusion.

Differentiated instruction should be central to lesson planning, ensuring that the diverse needs of all learners, including those with hearing impairments, are met. Creating a supportive and inclusive classroom environment where every learner feels valued is key to fostering academic growth and social belonging. Teachers should also pursue continuous professional development focused on inclusive education, deaf education, and innovative instructional techniques to remain current and effective in their practice.

Institutionalizing these teaching models in both inclusive and non-inclusive settings is essential. Teacher training programs must emphasize co-teaching methods and experiential design. Additionally, access to interpreters, visual tools, and hands-on materials should be prioritized. Cross-classroom collaboration and routine assessment of instructional impact will further enhance outcomes. Teachers are encouraged to build research-informed practices that empower all learners, especially deaf students, to thrive in mathematics education.

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