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Fostering conceptual understanding through collaborative learning in South African Mathematics classrooms: A mixed method study

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ABSTRACT

The study explores collaborative learning as an inclusive pedagogical innovation to enhance conceptual understanding in South African mathematics classrooms. Although policy-driven curriculum reforms promote learner-centred approaches, most classrooms still prefer rote learning and procedural teaching, perpetuating ongoing gaps in achievement and engagement. Addressing these challenges, this research investigates how collaborative group activities can deepen mathematical understanding and encourage meaningful participation among diverse learners. Employing a mixed-methods design, this study involved 103 Grade 9 learners and five mathematics educators from two public schools in Gauteng Province. Data was collected through classroom observations and pre- and post-intervention assessments. Quantitative analyses using paired-samples t-tests revealed significant gains in conceptual understanding following the collaborative initiative. Thematic analysis of quantitative data underscored enhanced engagement, reinforced peer support networks, and openness to exploring complex mathematical ideas. The findings highlight the role of collaborative learning in fostering both inclusive participation and conceptual mastery, demonstrating specific benefits for learners who have historically struggled with mathematics. The study stresses the need for professional development of educators centred on inclusive facilitation strategies, purposeful group structuring, and adaptive classroom methodologies. By integrating social constructivist and inclusive education theories, this study provides empirical evidence and practical guidance for educators and policymakers aiming to transform mathematics classrooms into dialogic, learner-centred environments that reflect the lived realities of South African diverse learners. The study improves the scholarship of teaching and learning by illuminating new avenues towards equity, deeper understanding, and sustainable pedagogical transformation.

Keywords: Collaborative Learning, Conceptual Understanding, Inclusive Education, South African Classrooms, Social Constructivism

INTRODUCTION

Mathematics education is a crucial yet challenging domain worldwide, with persistent concerns related to learner disengagement, misunderstandings of concepts, and inequities in achievement.[1] In numerous

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South African classrooms, despite curriculum reforms that promote learner-centered teaching methods, traditional instructional approaches that emphasise rote learning and procedural tasks still prevail.[2] This lack of progress limits the ability of learners to develop profound conceptual understanding and meaningful engagement, particularly among historically marginalised and diverse learner groups.

In mathematics, conceptual understanding refers to a learner's ability to grasp underlying principles and relationships rather than merely memorising procedures. Understanding is critical for effective problem-solving, knowledge transfer, and lifelong learning.[3] However, attaining this level of understanding requires instructional strategies that encourage active engagement, dialogue, and reflective thinking.[4] Collaborative learning, based on social constructivist principles, presents a promising opportunity to realise these goals by promoting peer interaction, the co-construction of knowledge, and inclusive classroom environments.[5]

Furthermore, inclusive education demands pedagogical innovations that accommodate the varied needs of learners, breaking down language barriers, prior knowledge, and socio-economic inequalities.[6] Collaborative learning, when intentionally designed, can foster creative, supportive spaces where all learners participate equitably, thereby aligning with both curriculum aspirations and the principles of social justice.[7]

Despite the theoretical promise, empirical data on how collaborative learning enhances conceptual understanding within the South African mathematics classrooms remain limited.[8] Additionally, teacher readiness and the essential facilitation strategies for inclusive collaboration have not been thoroughly explored.[9] The study aims to fill this gap by investigating the effects of

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collaboratively structured problem-solving tasks on the conceptual understanding of grade 9 learners in two public schools in Gauteng Province. Rooted in social constructivist and inclusive education principles, the research responds to the demand for impactful, contextually relevant, and equity-focused Scholarship of Teaching and Learning (SoTL).[10]

The study is directed by the following questions:

1. To what extent does collaborative learning enhance the conceptual understanding of mathematics among Grade 9 learners?
2. In what ways do learners experience collaborative group work in terms of engagement, participation, and support?
3. What inclusive facilitation strategies do educators employ, and how do these affect learning outcomes?

By emphasising collaborative learning as an inclusive innovation within real classroom contexts, this research provides empirical evidence and practical insights to transform the teaching of mathematics in South Africa. It supports the theme of the special issue by approaching the SoTL differently through experimental, learner-centred strategies that innovate pedagogy and theory in response to the real experiences of learners.

LITERATURE REVIEW

Collaborative learning is defined as an educational approach in which two or more individuals collaborate on a shared task, such as a project or problem, to achieve mutual understanding or create a product.[11] As noted by Yang, collaborative learning is founded on the principle that learning is a naturally social endeavour in which individuals share ideas and meaning.[12] Collaborative learning serves as a strategy that is deliberately designed, wherein the instructor organises learning activities to promote and necessitate interaction, dialogue, and collective construction of knowledge among learners.[13] This approach goes beyond the grouping of learners. It involves a purposeful transformation of the teacher's role and the classroom dynamics of interaction.

The pedagogical approach emphasises the importance of communication, joint problem-solving, and the co-construction of knowledge, providing significant advantages in mathematics education where a profound conceptual understanding is critical.[14] Unlike conventional, teacher-centred models that prioritise individual rote memorisation of algorithms, collaborative learning positions learners as active participants in knowledge creation.

Research shows that collaborative interactions enable learners to articulate their reasoning, address misconceptions, and internalise mathematical concepts.[15] For instance, when learners explain their thought processes to their peers or consider alternative viewpoints, they engage in reflective

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practices essential to move from procedural fluency to relational understanding.[16] Consequently, this social dimension of learning fosters higher-order thinking.

In many educational settings, including South Africa, mathematics continues to pose challenges for many learners, partly because teaching methods treat knowledge as isolated facts rather than integrated concepts. By engaging in collaborative learning, learners have the opportunity to bridge this gap, interacting in ways that foster curiosity and deepen inquiry.[17] However, it is crucial that collaborative learning is deliberately structured to optimise engagement and ensure constructive interdependence among group members.[18]

Inclusivity in mathematics education

Inclusive education encompasses practices that ensure all learners, regardless of their abilities, language backgrounds, or socio-economic conditions, are afforded equal opportunities to learn and participate meaningfully.[19] This concept of inclusive education extends well beyond physical placement within a conventional classroom; it signifies a transformative process that involves the adaptation of the educational system itself, including its culture, policies, and practices, to address the diverse needs of every learner.[20]

Inclusive mathematics education actively develops lessons that integrate multiple entry points, representations, and expressions, ensuring that every learner is fully engaged and demonstrates a deep understanding of mathematics.[21] In the mathematics classroom, where disparities are especially evident due to language barriers and differences in prior knowledge, inclusive pedagogy is vital for bridging achievement gaps and fostering a sense of belonging.[22]

Collaboration stands out as a particularly powerful tool for fostering inclusion because it facilitates peer support, solidarity, and differentiated learning experiences. Group activities motivate learners who may struggle individually to engage in ways that improve their confidence and competence.[23] Moreover, cooperative learning environments disrupt traditional classroom hierarchies by valuing diverse ways of thinking and cultural insights, better reflecting learners' lived experiences.[24]

Nonetheless, collaborative learning is not automatically inclusive; it requires intentional design and proficient facilitation. Educators must encourage respectful dialogue, equitable participation, and customise tasks to meet learners' needs, ensuring that no learner is marginalised or left passive.[25] Therefore, teacher professional development on inclusive collaborative facilitation is essential to realise the inclusive potential of collaborative learning

THEORETICAL FRAMEWORK

This study is based on Vygotsky's social constructivist theory, which posits that cognitive development takes place through social interaction within the Zone of Proximal Development (ZPD).[26] The ZPD

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defines the gap between what the learner can achieve independently and what they can achieve with the help of more knowledgeable peers or adults.[27] Collaborative learning creates an environment in which such assisted learning can take place, as learners scaffold each other's thinking through dialogue and collaborative problem-solving.[28]

Social constructivism emphasises the role of language and culture in influencing learning, making it particularly pertinent for multilingual and culturally diverse classrooms like those in South Africa. Within this framework, knowledge is not merely transmitted but constructed collectively through negotiation, reflection, and creation of shared meanings.[29]

In addition, the theory of inclusive education espouses the principle that every learner, regardless of background or ability, has the right to learn and participate fully in a shared setting.[30] Inclusive education transcends mere integration by recognising diversity as an asset, emphasising the development of supportive, flexible, and accessible learning spaces through tailored assistance, challenging curriculum, varied instructional approaches, and cooperative communities.[31]

Its objective is to eliminate barriers to learning and participation, ensuring fairness and feelings of belonging for each learner in the school community.[32] In summary, this theory highlights the principles of equity, appreciation for diversity, and empowerment of all learners.[33]

The theory of Inclusive education encourages educators to modify their pedagogical approaches and classroom environments to accommodate diverse learner profiles, thereby removing barriers to participation. Inclusive education requires that collaboration be intentionally structured to foster democratic, dialogue learning communities where every voice is heard and valued.[34]

Vygotsky's social constructivist theory, along with inclusive education theory, provides a strong foundation for collaborative learning to improve conceptual understanding in mathematics classrooms throughout South Africa. Vygotsky posits that learning is a social process that occurs through interaction and dialogue within the ZPD, where learners collectively construct knowledge with more knowledgeable peers or educators.[35] This highlights the importance of peer collaboration in advancing learners' mathematical understanding.

The theory of inclusive education enhances this by promoting classrooms that embrace diversity and ensure active involvement from all learners, regardless of their abilities. It advocates for equitable learning settings that recognise the differences and promote mutual assistance, which is essential to the varied contexts of South African schools.[36] Together, these theories endorse collaborative learning strategies that establish inclusive environments where learners can improve their understanding of mathematics through collective problem-solving and dialogue.

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[31] Kunwar and Adhikari, "An Exploration of the Conceptualization, Guiding Principles, and Theoretical Perspectives of Inclusive Curriculum"; Sarika Sharma, "Enhancing Inclusive Learning Environments: Strategies for Curriculum Adaptation and Modification," *Future of Special Education in India* 109 (2024): 121.

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[36] Kunwar and Adhikari, "An Exploration of the Conceptualization, Guiding Principles, and Theoretical Perspectives of Inclusive Curriculum."

The integration of Vygotsky's social constructivist and inclusive education theories is significant, as it promotes a learning environment where social interaction and diversity foster understanding and participation among all learners. This combined methodology mitigates educational disparities by ensuring that each learner, regardless of background or ability, receives support through scaffolded and collaborative learning experiences.

The integration promotes equity and enhances academic outcomes by recognising each learner's contributions and potential within the classroom community. Collectively, these frameworks direct the study towards exploring not only whether collaborative learning improves mathematical understanding but also how it can be applied to encourage inclusive participation.

CONCEPTUAL FRAMEWORK

Drawing on Vygotsky's social constructivist and inclusive education theories, this study's conceptual framework positions learning structures and inclusive facilitation as crucial components that enhance the learning process. Collaborative learning corresponds with Vygotsky's emphasis on social interaction as a vital catalyst for cognitive development, whilst inclusive facilitation reflects the principles of creating an equitable learning environment that accommodates all learners, including those with learning challenges or coming from marginalised backgrounds.

These inputs affect several mediating processes essential for achieving successful learning outcomes. Firstly, the quality of peer interaction is crucial, as learners communicate, negotiate ideas, and offer mutual support in group settings. This interaction is vital for co-constructing knowledge and scaffolding each learner's progress within their ZPD, as outlined by Vygotsky. Secondly, learner engagement reflects learners' active participation, motivation, and readiness to collaboratively explore intricate mathematical concepts. Thirdly, a feeling of belonging is fostered when learners perceive themselves as valued and included in the classroom community. This is particularly important for marginalised learners, together with those with additional learning requirements. Such a sense of belonging enhances participation and emotional commitment in learning.

Together, these mediating processes influence key outcomes that this research aims to achieve. Enhanced conceptual understanding is evident when learners develop a deeper, more adaptable grasp of mathematical concepts, enabling them to address problems creatively and accurately. Inclusive participation guarantees that all learners have fair opportunities to contribute actively, fostering classroom democracy and reflecting the tenets of inclusive education. The study, through this conceptual framework, highlights how the interaction of inclusive teaching practices and collaborative learning can promote meaningful mathematical understanding and fair engagement for all learners in South African classrooms.

The conceptual framework of this study, as shown in Figure 1 below, visually depicts the key elements and their relationships that underpin the exploration of collaborative learning and inclusivity in mathematics classrooms. Based on social constructivist and inclusive education theories, the framework organises the study's vital inputs, mediating processes, and desired outcomes, providing a clear guide for understanding how collaborative learning enhances conceptual understanding and inclusive participation.

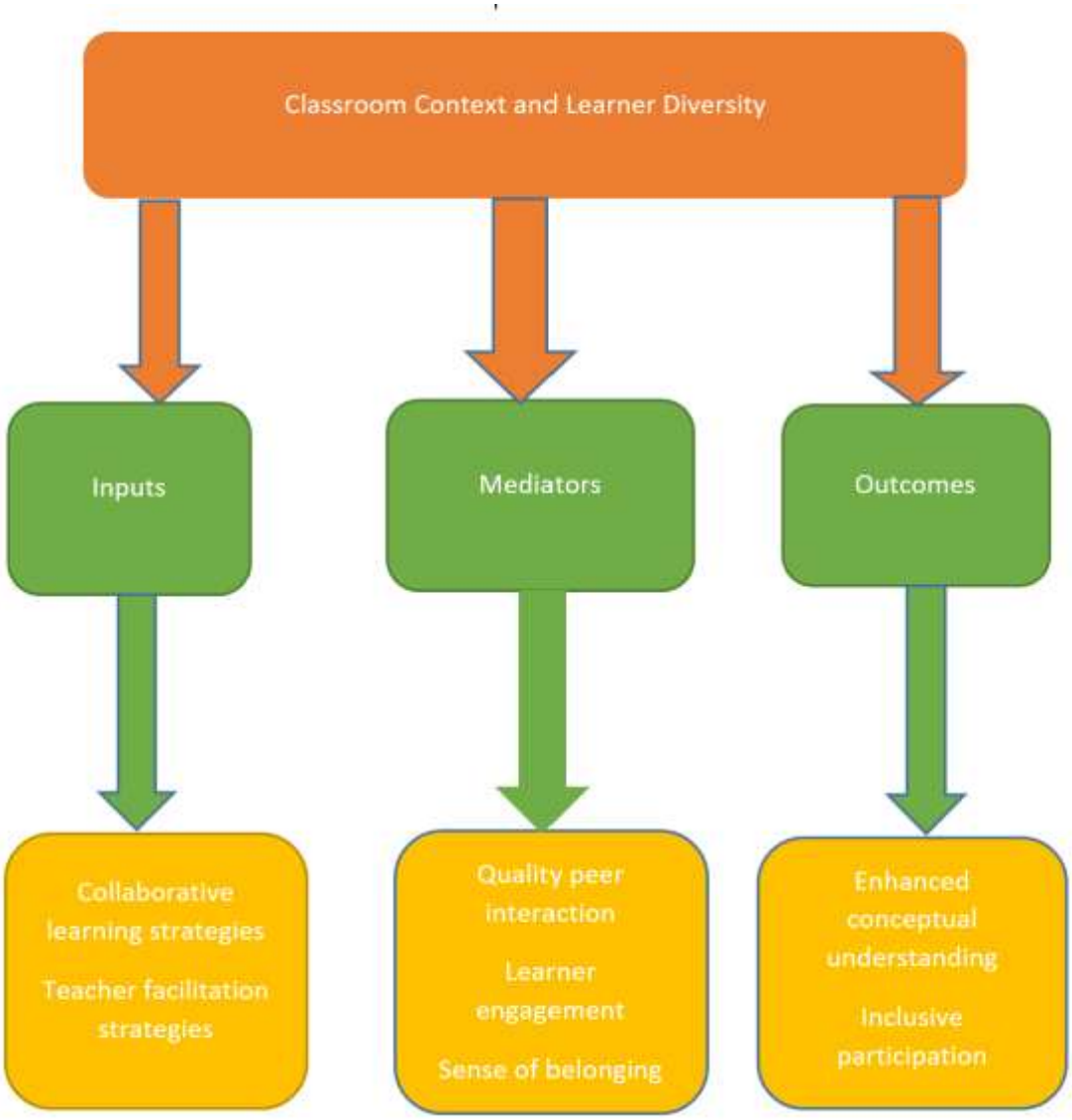

Figure 1: Conceptual Framework for Collaborative Learning and Inclusivity in Mathematics

This figure demonstrates how collaborative learning strategies and inclusive teacher facilitation serve as key inputs that shape mediating processes, including the quality of peer interaction, learner engagement, and a sense of belonging. Collectively, these mediators lead to enhanced conceptual understanding and inclusive participation in mathematics classrooms.

The conceptual framework provides a theoretical lens and a practical guide for exploring and implementing collaborative learning as a transformative pedagogy that promotes cognitive development and social justice in various mathematics classrooms in South Africa.

METHODOLOGY

This study utilised a mixed-methods research design, specifically an explanatory sequential design, to examine the effects of collaborative learning on conceptual understanding and inclusivity in South African mathematics classrooms. This approach facilitated the collection of both quantitative and qualitative data, thereby offering a comprehensive understanding of the phenomenon by first quantitatively evaluating the intervention's impacts, followed by a qualitative exploration of learners' and educators' experiences and perceptions. The mixed-methods design ensured that statistical outcomes were enriched with contextual depth and human insights, in line with the study's objective of understanding the lived realities in the classroom.

Research Design

The study employed a quasi-experimental design, incorporating a pre- and post-test integration model. This design was selected because of the practical constraints associated with random assignment in real school settings. Quantitative data were obtained through pre- and post-tests to assess changes in learners' conceptual understanding of mathematics. Qualitative data were collected through classroom observations and structured interviews to investigate the dynamics of collaborative learning, which included learner engagement, peer support, and teacher facilitation techniques. This multifaceted approach offered a strong method for triangulating findings and confirming conclusions.

Participants and Sampling

Participants of this study comprised one hundred and three (103) Grade 9 learners and five (5) mathematics educators from two public secondary schools situated in the Gauteng Province of South Africa. These schools were intentionally selected for their accessibility, willingness to participate, and potential to implement a collaborative learning intervention within their mathematics programs. Grade 9 learners were selected as participants because they were at a critical stage for cultivating abstract mathematical concepts and problem-solving abilities, which are vital for progression in the South African educational framework.

Learner participants were selected from existing mathematics classes at the two schools to minimise disruption to the school timetable. The teachers involved were those responsible for teaching the participating Grade 9 classes. The sample was designed to reflect the diversity commonly found in South African public school settings, taking into account their different socio-economic backgrounds and previous academic performance. Ethical considerations, including informed consent from parents/guardians and learners' assent, as well as permission from school authorities and the Department of Education, were strictly followed throughout the recruitment process.

Data collection instruments

The following three primary instruments were utilised for data collection: pre- and post-tests, classroom observations, and structured interviews.

Mathematics conceptual understanding Tests (Pre- and Post-tests)

A test for conceptual understanding was created to assess understanding of key Grade 9 concepts, particularly algebraic reasoning and problem-solving. The test included short questions requiring conceptual application and open-ended problems that required an explanation of reasoning. The test was conducted as a pre-test before the intervention and a post-test immediately after. The test's content validity was ensured by alignment with the South African Curriculum and Assessment Policy Statement (CAPS) for Grade 9 mathematics and by review by qualified mathematics educators.

Classroom observations

Classroom observations were conducted using a structured protocol to record the temporal dynamics of collaborative learning groups. The observations focused on key aspects such as Learner engagement and participation in group activities, the types and quality of peer-to-peer interactions (for example, scaffolding, explanations, disagreements), the teacher's role in facilitating group work and fostering inclusivity, and the use of collaborative learning materials and tasks.

Structured interviews

Structured interviews were conducted with both the participating Grade 9 learners (12 learners chosen for a diverse range of performance and engagement) and five mathematics educators. The purpose of the interviews was to gather detailed perceptions and experiences related to: the effectiveness of collaborative learning in enhancing conceptual understanding, challenges and benefits of group work, perceived shifts in engagement, confidence, and peer support, and educators' perspectives on implementing collaborative learning, which included successes, challenges, and professional development needs. Interview questions were crafted to enhance quantitative data and observational

findings, offering a deeper understanding of the 'how' and 'why' behind the observed outcomes. Interviews were audio-recorded and transcribed word-for-word for later thematic analysis.

Intervention: Collaborative learning activities

The core aspect of the intervention in this study involved implementing group-oriented problem-solving activities over eight weeks. These activities were intentionally designed to foster conceptual understanding rather than memorisation, stimulate active dialogue and peer teaching, require interdependence among group participants for effective completion, and ensure accessibility and engagement for learners with varied mathematical backgrounds and learning preferences.

Before the intervention, the five participating mathematics educators were engaged in a professional development workshop that concentrated on the principles of collaborative learning strategies for inclusive group facilitation and the design of effective tasks. This training ensured uniform implementation of the intervention in classrooms and equipped educators with the skills to effectively manage group dynamics. Learners were organised into heterogeneous groups consisting of four to five members, ensuring a diverse mix of abilities and backgrounds to enhance peer scaffolding and promote inclusive participation.

Data analysis

Quantitative data analysis

Quantitative data from the pre- and post-tests were analysed utilising paired sample t-tests. This statistical approach was selected to determine whether there was a statistically significant difference in learners' conceptual understanding scores before and after the collaborative learning intervention. Data were analysed using SPSS statistical software, with a significance threshold set at $p<0,05$. Additionally, descriptive statistics, including means and standard deviations, were computed to summarise test performance.

Qualitative data analysis

Qualitative data from classroom observations and structured interviews were examined using thematic analysis. This process involved a systematic approach to reading and re-reading the transcribed data and field notes to pinpoint recurring patterns, concepts, and themes related to learner engagement, peer interaction, educator facilitation, and the perceived impact on understanding and inclusivity. The analysis adhered to the established steps of thematic analysis: familiarising with data, initial coding, searching for themes, reviewing themes, defining and naming themes, and compiling the report. To enhance the trustworthiness and credibility of the findings, a triangulation of qualitative data sources was employed, including observations and interviews.

Ethical considerations

Before commencing the study, ethical approval was obtained from the appropriate university ethics committee. Permissions were obtained from the Gauteng Department of Education and the principals of the schools involved. Informed consent was secured from parents and/or guardians for all learner participants, and learners themselves provided assent. Educator participants also gave their informed consent. The confidentiality and anonymity of all participants were maintained throughout the study by using pseudonyms for schools, educators, and learners in all data presentations. Participants were informed of their right to withdraw from the study at any time without penalty.

PRESENTATION OF FINDINGS

This section synthesises and interprets both quantitative and qualitative data in alignment with the study's three research questions, grounded within the theoretical frameworks of social constructivism and inclusive education, and the conceptual framework, adhering to the established practices for mixed-methods integration. The findings revealed how collaborative learning influenced the learners' conceptual understanding and inclusive participation in grade 9 mathematics classrooms in South Africa.

Theme 1: collaborative learning and conceptual understanding

Addressing the first research question, the quantitative findings demonstrate a statistically significant enhancement in learners' conceptual understanding following the collaborative learning intervention. The average pre-test score of 47,1% with a standard deviation of 13,2 rose to 64,8% and 14,1 standard deviation post-intervention, with a paired-samples t-test validating this gain as statistically significant ($t(102) = 8,97$; $p<0,001$). In particular, gains were observed across all performance quartiles, particularly among learners who scored less than 40%, who advanced from 32,3% to 53,7%. This pattern aligns with the conceptual framework's postulate that collaborative learning strategies, as inputs, enhance outcomes through mediators such as quality peer interaction.

Social constructivism helps elucidate these results, highlighting that knowledge is co-constructed through social negotiation and scaffolding within the ZPD.[37] The collaborative problem-solving groups offered structured opportunities for learners to articulate their reasoning, challenge misconceptions, and enhance their mathematical understanding. This confirms the framework's assertion that collaborative learning promotes a deeper and more adaptable conceptual understanding beyond mere procedural skills.

Theme 2: learner engagement, peer support, and inclusive participation

Qualitative findings shed light on the lived experiences that contribute to these cognitive gains. Classroom observations and interviews indicate that collaborative learning significantly increases active learner engagement, which is a key mediator in the conceptual framework. Learners reported feeling more interested and less afraid to share ideas, and demonstrated greater readiness to explore complex mathematical problems collaboratively.

Peer support surfaced as a recurring theme. Learners frequently scaffolded each other by clarifying solutions and providing different viewpoints, which not only reinforced social constructivist principles but also reduced anxiety, a barrier often experienced in traditional classrooms. Educators noted that learners were 'less anxious' and more willing to ask questions in groups than individually. The equitable contributions of previously reserved or struggling learners underscore the fundamental role of inclusive participation in the framework. Diverse groups stimulated richer mathematical discussions and enhanced overall classroom democracy.

Together, these qualitative themes demonstrate how collaborative learning stimulates mediators of engagement, peer interaction quality, and sense of belonging, fostering inclusive participation in line with the principles of inclusive education.[38]

Theme 3: Teachers' inclusive facilitation and professional growth

The third research question concerned educators' role in facilitating collaborative learning. Observation showed educators transitioning from being the sole providers of knowledge to facilitators, encouraging dialogue and critical thinking. They circulated among groups, asked insightful questions, and fostered an environment where each learner felt included and valued, actualising the framework's emphasis on inclusive facilitation as an essential component.

Educators expressed the necessity for ongoing professional development to effectively manage group dynamics and design suitably challenging collaborative tasks. This observation underscores the importance of educators' facilitation skills in sustaining mediators, including peer quality engagement and belonging, which link instructional inputs to improved outcomes, thus affirming the dual pedagogical role highlighted in the conceptual framework.

Summarising the findings

In summary, this study's findings confirm that structured collaborative learning, supported by inclusive teaching methods, significantly improves the conceptual understanding of mathematics among Grade 9 learners, whilst fostering greater learner engagement and equitable participation. The alignment

[37] Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*.

[38] Kunwar and Adhikari, "An Exploration of the Conceptualization, Guiding Principles, and Theoretical Perspectives of Inclusive Curriculum."

between quantitative gains, qualitative experiences, and educator practices validates the conceptual frameworks and reinforces the social constructivist and inclusive education theories underpinning this research. The findings provide strong evidence for adopting collaborative learning as an effective, equity-focused approach in South African mathematics classrooms.

Table 1 below integrates the study's quantitative and qualitative findings with key theoretical constructs derived from social constructivism and inclusive education. It highlights the role of collaborative learning and inclusive facilitation as inputs that influenced mediators such as peer interaction, learner engagement, and sense of belonging, ultimately resulting in enhanced conceptual understanding and inclusive participation in Grade 9 mathematics classrooms.

Table 1: Integration of Quantitative and Qualitative Findings with Theoretical Constructs in Collaborative Learning for Inclusivity

Theoretical Construct	Quantitative Findings	Qualitative Findings	Interpretation / Mediators
Collaborative Learning (Input)	Significant gains in conceptual understanding (pre: 47.1%, post: 64.8%, $p < 0.001$)	Increased learner engagement and peer support observed	Collaborative tasks fostered peer interaction and scaffolded learning
Social Constructivism	Improvement across all performance quartiles; low-achieving learners showed notable gains	Learners articulated thinking, challenged misconceptions, peer scaffolding evident	Knowledge co-construction via social negotiation in ZPD
Inclusive Participation	Gains more pronounced among lower quartile learners	Learners felt safer, less anxious, more willing to contribute; equitable group participation	Sense of belonging and reduced anxiety increased participation
Teacher Facilitation (Mediator)	Not directly quantified	Teachers facilitated dialogue, monitored groups, supported inclusive environment	Educators' role critical for sustaining engagement and inclusion

The table systematically arranges the complex interplay between key components of the study, demonstrating how collaborative learning and inclusive teaching practices jointly contribute to improved learner outcomes. It serves as a visual overview that elucidates the connections among theory, data, and practical implications for promoting conceptual understanding and inclusivity in mathematics classrooms.

The study's conceptual framework was maintained, demonstrating that inputs such as collaborative tasks and facilitation influenced mediators, including peer interaction, engagement, and a sense of belonging, which led to favorable outcomes, namely conceptual understanding and inclusive participation.

DISCUSSION

The discussion analyses the findings in the context of social constructivist and inclusive education theories, responding to the research questions, and situates the results within the wider context of educational scholarship and practice.

Impact on conceptual understanding

The notable gains in conceptual understanding align with Vygotsky's theory, which posits that knowledge is socially constructed through interactions within the ZPD.[39] Collaborative learning groups offered structured scaffolding opportunities that allowed learners to articulate their reasoning, address misconceptions, and gain a deeper understanding. This empirical confirmation of the conceptual framework highlights the critical role of quality peer interaction as a mediator that translates collaborative learning inputs into cognitive growth.

Furthermore, the pronounced improvements observed among learners who initially performed poorly highlight the promise of collaborative learning, integrated with inclusivity, to bridge deep-seated achievement gaps, a crucial issue in the South African education context characterised by historical inequities.[40] These findings validate collaborative learning not only as a tool for mastery but also as a vehicle for promoting educational equity.

Learners' engagement and experiences

Quality findings reveal how collaboration fundamentally shifts classroom dynamics by enhancing engagement, motivation, and social support. The increased confidence and willingness to share their ideas align with the principles of inclusive education, which underscore the importance of belonging and valuing diverse contributions.[41] The documentation of peer scaffolding further aligns with social constructivist perspectives, highlighting the roles of language, culture, and community in shaping learning.[42]

The reconceptualisation of classroom interaction expands the existing SoTL knowledge, illustrating how intentionally structured collaboration can meaningfully counter traditional rote instruction. This dialogic learner-centred environment serves as a model for approaching SoTL differently, establishing spaces where learners have ownership of their learning processes.

Educators as inclusive facilitators

The study emphasises the instrumental role that educators play as facilitators, not simply transmitters of knowledge. Their transition towards guiding collaborative dialogue supports the conceptual framework's position of educator-inclusive facilitation as a vital input that stimulates mediators such as learner engagement and peer quality interaction. This supports broader educational reforms aimed at fostering more interactive and equitable learning environments.[43]

Nonetheless, the findings also reveal certain challenges. Educators expressed the need for ongoing, context-specific professional development focused on managing group diversity and designing effective collaborative tasks. This underscores the ongoing need for educator capacity-building to support inclusive pedagogical innovation.

Broader implications and contributions

The study combines theoretical frameworks, empirical data, and the actual experiences within South African mathematics classrooms to present collaborative learning, enhanced by inclusive facilitation as a highly effective approach. By applying the conceptual framework in real-world settings, this

[39] Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*.
[40] Spaull, "Poverty and Privilege: Primary School Inequality in South Africa."
[41] Kunwar and Adhikari, "An Exploration of the Conceptualization, Guiding Principles, and Theoretical Perspectives of Inclusive Curriculum."
[42] Ernest, "Mathematics and Values."
[43] Chang Xu, "Exploring Visiting Artists' Dual Roles and Constraints in Art Educational Programmes," *International Journal of Art & Design Education* 43, no. 1 (February 29, 2024): 67–81, https://doi.org/10.1111/jade.12493.

research contributes a nuanced model that can be utilised in future research and pedagogical design to foster equity and conceptual depth in mathematics education.

The findings have implications that reach beyond local contexts, responding to global educational imperatives for inclusive, socially just, and learner-centred practices. This work enriches the discourse on the SoTL by exemplifying how well-founded, theory-driven interventions can produce measurable, meaningful improvements for a diverse range of learners.

Limitations

Although this study offers significant insights into the role of collaborative learning in fostering inclusivity and conceptual understanding within South African mathematics classrooms, it is essential to acknowledge its limitations. Firstly, the sample comprised grade 9 learners from selected schools, which may limit the applicability of the findings to other grades or contexts. Secondly, the intervention's duration constraints may have limited the ability to observe long-term impacts on mathematical understanding and participation. Thirdly, the challenges related to language diversity and proficiency prevalent in South African classrooms may have influenced both group dynamics and learner engagement, as some learners relied on code-switching to fully grasp the concepts.

Additionally, whilst mixed methods were used to capture rich data, the qualitative component could be expanded to include more extensive longitudinal investigations into the experiences of both learners and educators. Finally, educators reported difficulties managing group dynamics, underscoring the need for further research on differential facilitation strategies that effectively address learners' diverse needs.

RECOMMENDATIONS

Based on the study's findings and limitations, the following recommendations are suggested for practice, policy, and future research.

For educators

- Implement structured collaborative learning environments using diverse group task formats such as problem-solving challenges, jigsaw activities, and peer teaching to enhance deeper conceptual understanding.
- Apply role rotation within groups (for instance, facilitator, recorder, presenter, checker) to ensure fair participation and cultivate diverse skills among all learners.
- Provide deliberate educator training on facilitation techniques that promote inclusive dialogue, scaffold learner reasoning, and effectively manage group dynamics.
- Implement language-inclusive pedagogies such as code switching and peer translation to support multilingual learners and minimise language barriers during collaboration.

For policy makers and curriculum developers

- Incorporate specific collaborative learning strategies, such as structured group roles and scaffolded tasks, within curriculum frameworks and assessment guidelines.
- Ensure resources and educator professional development target facilitation skills and inclusive teaching practices for educators, particularly in under-resourced schools.

For researchers

- Explore longitudinal effects of specific collaborative strategies, such as role rotation and task scaffolding, on conceptual understanding and learner inclusion.
- Investigate facilitation strategies designed to address language barriers and accommodate diverse learner abilities within group tasks.
- Examine how collaborative learning influences the development of learner identity, agency, and confidence in the field of mathematics.

CONCLUSION

This study has demonstrated that when collaborative learning is intentionally designed and closely managed, it greatly enhances learners' conceptual understanding of mathematics whilst promoting active and equitable participation in South African classrooms. Firmly grounded in the principles of social constructivism and inclusive education, the intervention established dialogic spaces where learners collaboratively built knowledge, supported one another, and developed confidence. Educators played a pivotal role as the facilitators of inclusive collaboration. However, ongoing professional development specifically designed to address the complexities of diverse classrooms remains necessary to enhance long-term impacts. By triangulating robust quantitative gains with in-depth qualitative insights, this research offers compelling evidence and a practical framework for revolutionising mathematics education in ways that respond to the diverse realities of learners. As a contribution to SoTL, the study demonstrates how innovative, equity-driven, and context-responsive pedagogical approaches can promote deeper, more inclusive learning. It invites educators, policy-makers, and researchers to embrace, modify, and enhance collaborative learning as a catalyst for educational transformation.

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