

PROMOTING MATHEMATICS THROUGH MUSIC EDUCATION IN RURAL-BASED PRIMARY SCHOOLS IN SOUTH AFRICA: A SYSTEMATIC REVIEW

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Abstract: *In rural South African primary schools, mathematics achievement remains low due to limited resources and culturally misaligned teaching methods. Music, deeply rooted in local traditions, offers potential to enrich mathematical understanding, yet little consolidated evidence exists on its effectiveness in such contexts. This study aims to systematically review how music education enhances mathematics learning in rural South African primary schools through integrated teaching strategies. Grounded in Embodied Cognition Theory, which links cognitive development to sensory and motor experiences, this framework supports analysis of rhythm and movement in learning. This study employed a Systematic Literature Review to investigate how music education has been used to promote mathematics learning in rural-based primary schools in South Africa. The study reviewed peer-reviewed empirical articles (2010–2025) from Scopus, ERIC, and Web of Science, focusing on music-math integration in rural settings. Findings show that music significantly improves learner engagement, comprehension, and memory retention, particularly when instruction draws on culturally familiar musical forms. Core mathematical concepts—such as sequencing, symmetry, multiplication, and fractions—are more effectively taught through music, as learners experience these concepts in embodied and repetitive formats that align with natural learning processes. Music also enhances classroom participation, reduces math anxiety, and fosters collaborative learning, especially among early-grade learners.*

Introduction

Mathematics remains one of the most challenging subjects for primary school learners in South Africa, particularly in rural schools where resource constraints, rigid curricula, and low learner motivation persist [17, 20]. Wang [24] reports that South African schools are among those providing the weakest mathematics instruction globally, and this has profound implications for learners' access to further education and knowledge-intensive careers. Similarly, Ngwenya and Chaba [17] highlight that mathematics learning across grades 1–12 remains a persistent challenge, especially in under-resourced schools. Emerging evidence suggests that integrating music into education can enhance learner engagement and mathematical understanding, due to music's transdisciplinary and contextually relevant nature [17, 23].

South Africa's education system continues to reflect historical inequalities rooted in

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the apartheid era. Despite more than 25 years of democratic governance, rural schools still struggle with limited access to quality teaching and learning materials [6, 15]. Mathematics, as a core subject, is particularly affected, with poor learner performance and high dropout rates. Research identifies multiple contributing factors, including teacher-centred approaches, learner-related challenges, school infrastructure, family and community influences, and broader environmental conditions [12]. These factors collectively undermine the quality of mathematics instruction and hinder learner achievement.

Music presents a promising yet underutilized avenue to support mathematics learning. It is a culturally embedded, accessible, and cognitively rich subject capable of enhancing abstract thinking, sequencing, pattern recognition, and spatial-temporal reasoning, all of which are critical for mathematics education [23]. International studies provide strong evidence of the cognitive overlaps between music and mathematics. For instance, Hibi [8] and Incognito, et al. [10] demonstrate that musical training supports logical-mathematical and cognitive development, particularly in early childhood. Activities such as rhythm games, singing exercises, and notation reading are associated with improved skills in counting, fractions, proportional reasoning, and pattern recognition [1, 7]. Furthermore, musical concepts such as melody, rhythm, scales, intervals, harmony, tuning, and temperaments align closely with mathematical concepts, including algebra, probability, trigonometry, geometry, numerical relations, integers, logarithms, and arithmetic operations [1]. These studies highlight music's potential to strengthen both mathematical reasoning and cognitive skills, supporting its integration into educational practice.

In the African context, indigenous musical practices often embody complex rhythmic structures and symmetrical patterns that can serve as natural entry points into mathematical concepts. Research suggests that rhythm, sequencing, and notation exercises can facilitate understanding of numerical relations, fractions, proportions, and patterns. Despite these promising findings, research on music-mathematics integration in South Africa remains limited and fragmented. Most studies focus on urban contexts or single case studies rather than providing a comprehensive view of rural educational settings [22, 23]. While Hendriks and Cruywagen [7] emphasize the potential of music to enhance mathematical understanding in the Intermediate Phase, particularly through rhythm and notation, such insights have not been systematically applied in rural schools.

Moreover, there is a lack of culturally responsive frameworks that incorporate indigenous music and local knowledge systems into mathematics instruction, limiting both the relevance and effectiveness of music-based strategies [15]. Theoretical foundations connecting music and mathematics, particularly from applied or computational perspectives, are underdeveloped. Most studies focus on pedagogical techniques rather than the underlying mathematical structures or models that could inform more rigorous practice [17]. Similarly, research on the long-term impact of music-integrated mathematics teaching on learner achievement is sparse. Systemic challenges—including teacher readiness, curriculum constraints, and resource limitations—further complicate the implementation of innovative strategies in South African schools [12, 20].

Despite these challenges, integrating music into mathematics instruction has shown potential to improve both learner achievement and attitudes toward the subject [11]. Over the past decade, teachers have experimented with a variety of instructional methodologies to develop music-mathematics curricula, demonstrating the feasibility and benefits of this approach [22, 23]. Indigenous musical traditions,

with their intricate rhythms and patterns, offer culturally meaningful pathways for introducing mathematical concepts, yet these have not been fully leveraged in rural South African classrooms.

Internationally, there is extensive evidence linking music and mathematics learning, particularly in early childhood and primary education. Musical training has been shown to enhance logical reasoning, memory, spatial-temporal skills, and pattern recognition, all of which underpin mathematical learning [8, 10]. These findings provide a compelling rationale for integrating music into mathematics education globally. However, local research contextualizing these insights to South Africa's unique socio-cultural and educational realities remains limited. Most South African studies focus on pedagogical interventions without fully exploring cognitive mechanisms or incorporating indigenous musical knowledge.

In summary, South African rural schools continue to face significant challenges in mathematics education due to historical inequalities, resource limitations, and systemic barriers. Music education represents an underexplored, culturally relevant, and cognitively supportive avenue to enhance mathematical understanding. Both international and local studies indicate strong connections between music and mathematics, but research in rural South African contexts remains fragmented and largely theoretical. There is a pressing need for robust, contextually grounded, and theoretically informed research that explores how music can be purposefully integrated into mathematics instruction to improve learner outcomes. Addressing these gaps could contribute to innovative, sustainable solutions for one of South Africa's most persistent educational challenges.

Research Questions

- a) How has music education been purposefully integrated to improve mathematics learning outcomes in rural South African primary schools?
- b) Which specific mathematical concepts are most successfully taught and reinforced using music-based instructional strategies in classrooms?
- c) What research frameworks and methodologies have been employed to assess the effectiveness of music-mathematics integration approaches?

Theoretical Framework

This study adopts Embodied Cognition Theory to explore how music education can enhance mathematics learning in rural-based primary schools in South Africa. Embodied cognition emphasises that thinking and learning are not solely mental activities but are fundamentally shaped through physical, sensory, and motor interactions with the environment. This framework is particularly relevant for music-integrated pedagogy because musical activities involve movement, rhythm, and repetition, all of which contribute to the development of mathematical understanding [5, 21].

In classroom contexts, learners engage in embodied practices such as clapping to rhythms, moving to beats, singing, and using body percussion. These activities link physical experiences with abstract mathematical concepts, including counting, fractions, sequencing, proportions, and pattern recognition. For instance, clapping in specific rhythmic patterns enables learners to internalise divisions of time and number sequences, while moving in time with music supports spatial-temporal reasoning and proportional understanding. Gesture-based musical games further

promote symmetry recognition and problem-solving skills, which are crucial for geometry and algebraic thinking [1, 7].

In the context of a systematic literature review, the effectiveness of music-integrated mathematics instruction is assessed through qualitative indicators rather than quantitative measures. These indicators include improved learner engagement, enhanced conceptual understanding, increased participation, greater enthusiasm for mathematics, and the ability to explain mathematical relationships verbally or through creative expression [11, 23]. Studies reviewed demonstrated that learners who participated in music-based activities showed deeper comprehension of abstract concepts and could apply these concepts in problem-solving activities within classroom contexts.

The following table summarises key links between music activities, mathematical concepts, and embodied cognitive processes as identified in the literature:

Music Activity	Mathematical Concept	Embodied Cognitive Process	Key References
Clapping to rhythmic patterns	Counting, fractions, division	Temporal sequencing, rhythm-motor coordination	[9]; [1]
Moving to beats or dance	Proportions, measurement, spatial reasoning	Spatial-temporal reasoning, body-environment interaction	[7];[5]
Body percussion	Patterns, symmetry, addition/subtraction	Sensorimotor integration, pattern recognition	[23]; [21]
Singing exercises with notation	Number sequences, fractions, ratios	Auditory-motor connection, symbolic representation	[1]; [11]

This framework demonstrates that embodied musical activities provide learners with culturally relevant, engaging, and effective pathways to develop mathematical understanding. It highlights how learning becomes meaningful when abstract concepts are connected to the body, environment, and sensory experiences.

Research Methodology: Systematic Literature Review (SLR)

This study employed a Systematic Literature Review to investigate how music education has been used to promote mathematics learning in rural-based primary schools in South Africa. According to Mohamed Shaffril, et al. [13], in a Systematic Literature Review (SLR), organisation and completeness are crucial. A clear research topic, precise study selection standards, and an extensive search across multiple databases are the first steps. To ensure fairness and transparency, only research that satisfy the requirements are presented [19]. The SLR provided a rigorous, transparent, and replicable method to collect, evaluate, and synthesise relevant empirical and theoretical research. The purpose was to identify effective interdisciplinary strategies, evaluate their educational impact, and explore how music-based learning enhances foundational mathematics in resource-constrained settings. The process consisted of three phases: searching, screening, and analysis.

Phase 1: Searching

The first phase involved a comprehensive search of peer-reviewed articles and grey literature published between 2010 and 2024, focusing on the last decade to capture recent developments in interdisciplinary education. The search was conducted across multiple academic databases known for educational and social science research, including Scopus, ERIC, Web of Science, and Google Scholar.

Boolean operators (AND, OR) were used to refine search results with combinations of the following keywords: *"Music and mathematics integration"*, *"Interdisciplinary learning in rural schools"*, *"Music education in South African primary schools"*, *"Mathematics through rhythm and movement"*, and *"Culturally responsive mathematics teaching"*. Additional sources such as reports from South Africa's Department of Basic Education were also reviewed to capture contextual insights relevant to rural schooling and arts-integrated pedagogy.

Phase 2: Screening

A systematic screening process was undertaken to ensure the inclusion of only high-quality and relevant literature.

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Empirical studies on integrating music in mathematics education	Studies unrelated to mathematics or music education
Research focused on primary education, particularly in rural or under-resourced settings	Publications not available in English
Peer-reviewed journal articles, policy reports, or programme evaluations	Theoretical papers without empirical evidence
Studies with evidence of learning outcomes or pedagogical models	Studies focusing solely on urban or secondary school contexts

Source: Researchers

The initial search yielded 1,100 articles. After removing duplicates, 750 unique records remained. Screening of titles and abstracts narrowed the selection to 130 articles for full-text review. Of these, 30 studies met all inclusion criteria and were retained for the final analysis.

Phase 3: Analysis

The final pool of 30 studies was analysed using thematic analysis to identify recurring concepts, frameworks, teaching strategies, and outcomes. Themes were developed both inductively and deductively, focusing on:

- The mathematical concepts most frequently taught through music, such as patterns, fractions, and sequencing
- Teaching approaches and classroom learning activities
- The role of cultural relevance in music selection and pedagogy
- Reported cognitive, affective, and behavioural outcomes among learners
- Challenges and opportunities in rural implementation

This approach enabled the synthesis of trends and gaps in the literature, providing a foundation for future research and policy development aimed at enhancing mathematics education through arts-integrated learning in rural South African schools.

Findings

Table 2 summarises the key themes emerging from the systematic analysis of the research questions. These themes capture the main patterns across the reviewed literature, illustrating how music education is used to support mathematics learning

in rural primary schools. The table also highlights the mathematical concepts most effectively taught through music, as well as the theoretical frameworks and methodological approaches used to evaluate the impact of integrating music with mathematics instruction.

Table 2: Emergent Themes from the Research Questions

Research Question	Emergent Theme and Description
How has music education been used to support mathematics learning in rural-based primary schools in South Africa?	Music as a Pedagogical Tool for Engagement: Music was used to enhance learner participation, motivation, and enjoyment in mathematics lessons, particularly in resource-limited rural contexts.
What mathematical concepts are most effectively taught through music-based approaches?	Conceptual Reinforcement through Rhythm and Patterns: Core mathematical concepts such as counting, fractions, patterns, and sequencing were effectively taught through rhythmic and musical structures.
What frameworks and methodologies are used in existing studies to evaluate the effectiveness of music-math integration?	Cultural Relevance and Contextual Integration: Indigenous and locally familiar musical forms made mathematics learning more relatable and meaningful for rural learners.

Music as a Pedagogical Tool for Engagement

Music is widely recognised as an effective pedagogical tool that enhances learner engagement in mathematics, especially in rural primary schools where conventional teaching methods may not resonate fully with learners [3, 7]. Azaryahu, et al. [3] highlight that although mathematics and music are often treated as separate disciplines, they have strong interconnections that can improve learning outcomes in both areas. Similarly, Hendriks and Cruywagen [7] argue that music’s harmonies, rhythmic patterns, and structures can enhance understanding of mathematical principles such as proportions, numerical relations, and arithmetical operations. Integrating musical activities such as singing, clapping, and rhythmic movement creates an interactive learning environment that fosters sustained attention and motivation [7]. This engagement is particularly important in rural contexts, where socio-economic challenges often negatively affect academic performance [12]. Music stimulates both emotional and cognitive domains, helping learners overcome math anxiety and build confidence [8]. Studies indicate that learners in rural South African classrooms show increased participation and enthusiasm when mathematics concepts are taught through music, suggesting that music serves as a bridge between abstract mathematical ideas and concrete experiential learning [10]. Engagement in music-based mathematics instruction also encourages collaborative learning, allowing learners to share knowledge and develop social skills.

Conceptual Reinforcement through Rhythm and Patterns

Musical structures such as rhythm, beat, and repetition naturally align with mathematical concepts, making music an effective medium for reinforcing foundational numeracy skills. Riebe [23] emphasises that music education is vital

for developing learners' literacy and numeracy skills, including reading, writing, listening, and speaking. Szabo et al [2] further assert that music supports learning across subjects, enhancing learners' critical thinking and problem-solving abilities. Concepts such as fractions, sequencing, patterns, symmetry, and counting are embedded in musical activities, allowing learners to understand abstract mathematical ideas through sensory and motor involvement [26]. Clapping to rhythms in time signatures, for example, helps learners internalise division and fraction concepts by physically experiencing parts of a whole [7]. Pattern recognition in music supports algebraic thinking and problem-solving skills [17]. These embodied experiences provide learners with multisensory input, deepening cognitive processing and retention [21]. Research in South African rural schools indicates that rhythm-based teaching enhances learners' ability to sequence numbers and develop proportional reasoning [12]. These findings support the growing consensus that music is a valuable tool for making mathematics accessible and meaningful.

Cultural Relevance and Contextual Integration

Research consistently shows that integrating indigenous music and culturally familiar musical forms into mathematics instruction enhances learner engagement and meaning-making in rural South African classrooms [14, 16]. Culturally relevant pedagogy recognises learners' backgrounds and prior knowledge, making learning more relatable and empowering [4, 15]. Quinn et al [25] observes that many rural learners engage daily with traditional songs, rhythms, and dances, which embody complex mathematical patterns and structures.

Incorporating these cultural practices into mathematics teaching bridges the gap between home and school learning environments [7]. Pradhan [18] supports this view, noting that aligning school instruction with home-based mathematical practices improves learner comprehension and engagement. Teachers can honour and preserve cultural customs while enhancing the mathematics curriculum by incorporating students' implicit mathematical knowledge derived from their ethnic and cultural backgrounds. This approach aligns with culturally responsive teaching principles, fostering inclusivity and countering the alienation often experienced by marginalised learners in mainstream curricula [20]. Studies indicate that learners demonstrate improved comprehension and motivation when familiar musical elements are used to explore mathematical concepts such as symmetry, repetition, and counting [17]. Contextual integration also supports the preservation of indigenous knowledge systems, enriching education with local cultural heritage.

Limitations

This review is limited by the relatively small number of studies focused explicitly on rural South African contexts, reflecting a broader scarcity of empirical research in this area. Studies often rely on qualitative methods, which, while rich in descriptive insights, may lack objective measures of learning outcomes. Publication bias and the underreporting of unsuccessful interventions may also influence the findings. Finally, the integration of music and mathematics is context-specific, and results from one rural community may not be directly transferable to others without considering cultural and environmental variations.

Discussions

This article has argued that the integration of music education into mathematics instruction offers a promising and contextually relevant approach to improving learner engagement and mathematical understanding in rural-based primary schools in South Africa. It has also highlighted that music—particularly through rhythm, repetition, and culturally grounded practices—serves as an accessible pedagogical tool that aligns well with the cognitive and emotional needs of learners in under-resourced environments.

The findings of this article mention that music is not only a tool for engagement but also a medium through which core mathematical concepts such as counting, sequencing, patterns, and fractions can be taught more effectively. Consistent with previous research [7, 8], the findings of the current chapter reveal that learners show greater enthusiasm and comprehension when mathematical instruction is linked to music-based activities. Evidently, music facilitates the embodiment of abstract mathematical ideas, allowing learners to physically experience and internalise concepts through rhythmic movement and auditory repetition.

The article findings show that such integration enhances not only academic outcomes but also learners' confidence and participation in the classroom [10]. These findings are in line with the theoretical framework of this article, which highlights that cognition is grounded in sensory and motor experiences, as explained by Embodied Cognition Theory [26]. By engaging learners' bodies and senses through musical activities, educators can create more holistic and inclusive learning environments, particularly for learners who struggle with abstract or language-heavy approaches to mathematics.

Scholars such as Muyambi and Ahiaku [15] have long emphasised the role of culturally relevant pedagogy in improving educational equity. The current article aligns with these scholars in showing that incorporating indigenous and familiar musical forms not only makes mathematics more relatable but also empowers learners by validating their cultural knowledge. Again, the findings of the current article show that when learners encounter mathematics through songs, rhythms, or dances they already know, they engage with the subject more confidently and with a deeper sense of ownership. This finding corroborates with the results of Taylor [20], who found that learners in disadvantaged contexts perform better when instructional methods are culturally and contextually aligned with their lived experiences.

The current article has established that while there is growing interest in music-mathematics integration globally, there remains a lack of empirical research specifically focused on rural South African primary schools. This is a significant gap, considering the persistent challenges faced by these schools, including overcrowded classrooms, limited teaching materials, and underqualified educators [12]. The review also indicates that while short-term improvements in learner engagement and comprehension are well-documented, there is limited longitudinal research evaluating the sustained impact of music-integrated mathematics instruction.

This finding is in congruence with the findings of previous studies [17] that emphasise the need for systemic innovation in mathematics education, particularly through interdisciplinary and multisensory learning approaches. However, the article also notes that most existing studies rely heavily on qualitative methods such as classroom observations and teacher reflections. There is a need for more robust, mixed-methods research that includes quantitative measurement of learner outcomes and cognitive gains over time. This will help establish stronger causal

links between music integration and improved mathematical performance.

The results of this article reveal that embodied, arts-integrated approaches can serve as a bridge between learners' cultural contexts and curriculum content. When music is used not as a separate subject but as a medium of instruction, mathematics becomes more meaningful, less intimidating, and more aligned with the cognitive and emotional development of learners. Importantly, the findings reinforce that teaching approaches which recognise and build upon learners' backgrounds are more likely to result in deeper learning and sustained interest in mathematics.

In light of these findings, the article supports calls for teacher training programmes to include modules on interdisciplinary teaching strategies and embodied learning theories. Many teachers in rural areas may not have formal music training but could greatly benefit from professional development that equips them with simple, culturally grounded musical techniques to support mathematics teaching. Incorporating such training can help bridge the gap between policy and practice, ensuring that innovative teaching methods reach the learners who need them most. The article has shown that integrating music into mathematics education in rural-based South African primary schools holds transformative potential. It enhances learner engagement, supports conceptual understanding, and fosters inclusive, culturally relevant pedagogy. These findings contribute to the growing body of research that promotes interdisciplinary, context-sensitive educational strategies, while also highlighting the urgent need for more empirical, long-term studies in this field. Future research should aim to develop scalable models of music-mathematics integration, assess their impact across diverse rural contexts, and inform curriculum reforms that reflect both the cognitive science of learning and the lived realities of learners.

Recommendations

Based on the findings of this systematic review, several key recommendations are proposed to enhance mathematics learning through music education in rural-based primary schools in South Africa:

1. **Integrate Music into Mathematics Curriculum Design:** curriculum developers should embed music-based learning strategies into the national mathematics curriculum, particularly for the Foundation and Intermediate Phases. Using rhythmic clapping, songs, and culturally familiar musical games to teach mathematical concepts such as counting, fractions, and patterns can enhance learners' understanding and retention.
2. **Develop Teacher Training and Professional Development Programmes:** teacher education programmes—both pre-service and in-service—should include modules on interdisciplinary teaching and Embodied Cognition Theory. Training should equip teachers with practical strategies to integrate music into mathematics lessons, even without formal musical backgrounds. Workshops and CPD programmes tailored for rural educators are essential.
3. **Promote Culturally Responsive Teaching Practices:** education stakeholders should encourage the use of indigenous and locally relevant music in teaching mathematics. Leveraging familiar songs and rhythms can help bridge learners' home and school environments, thereby promoting inclusivity, engagement, and deeper conceptual learning.
4. **Conduct Longitudinal and Mixed-Methods Research:** further empirical studies are needed to assess the long-term impact of music-integrated mathematics

instruction. Researchers should explore how such approaches influence learner performance over time, using both quantitative and qualitative methods to deepen understanding and inform policy.

Conclusion

The integration of music into mathematics education offers more than an interdisciplinary teaching technique; it presents a transformative pedagogical shift, especially within the context of rural-based primary schools in South Africa. This systematic review has revealed the significant potential of music to not only enhance learners' engagement with mathematical content but also to reimagine how foundational numeracy is taught in culturally diverse and resource-constrained environments. The insights gained point to the importance of shifting from compartmentalised subject teaching to more holistic, embodied learning approaches that reflect learners' everyday experiences and cultural expressions.

One of the most striking insights is how music-based teaching aligns with how children naturally learn—through movement, play, storytelling, rhythm, and repetition. These sensory-rich modes of learning, often sidelined in formal mathematics instruction, are intuitive to young learners, especially those in rural settings where oral traditions, community participation, and music are already central to their social development. This suggests that mathematics need not remain abstract or disconnected from learners' identities; rather, it can be internalised through familiar, joyful, and accessible forms of engagement. A second insight concerns the value of culturally embedded education in shaping learners' confidence and academic self-perception. Music-based mathematics, when grounded in indigenous knowledge systems, enables learners to see their culture reflected in the curriculum. This has implications for decolonising education by affirming the legitimacy of local knowledge and practices as foundations for learning. Such affirmation not only strengthens learner identity but also challenges deficit-based narratives often associated with rural education.

Furthermore, this review surfaces a growing need for education systems to adopt a more expansive view of pedagogical evidence. While the focus in policy circles often rests on large-scale quantitative assessments, this study underscores the importance of attending to qualitative indicators of learning—such as joy, participation, identity affirmation, and sustained interest. Music offers a unique lens through which these softer, yet equally vital, educational outcomes can be realised and assessed. An emerging consideration is the potential for music-mathematics integration to contribute to broader systemic goals, such as inclusive education, social cohesion, and multilingualism. Music transcends language barriers and offers a medium through which learners of different linguistic backgrounds can participate equitably. In this way, music becomes a tool not just for academic instruction but for social transformation—cultivating empathy, creativity, and community engagement in the learning process.

Finally, the review invites reflection on what it means to teach mathematics well. Beyond procedural fluency and test performance, effective mathematics education should nurture a sense of wonder, curiosity, and connection to the world. Music, in its universal and expressive power, has the capacity to awaken these qualities. The challenge moving forward is not only to prove its efficacy in conventional terms but to reframe educational success in ways that honour learners' diverse ways of knowing. In embracing music as a pathway to mathematical understanding, South

African rural schools are uniquely positioned to lead innovation rooted in cultural relevance, pedagogical integrity, and learner-centred transformation. This approach holds promise not only for academic improvement but for reimagining the very nature of what it means to learn.

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