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A Systematic Review of Music Education, Acoustics, and STEAM Integration in South African Primary and Lower Secondary Schools

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ABSTRACT

This systematic review investigates the integration of music education with science, technology, engineering, arts, and mathematics (STEAM) in South African basic schools. The study explores how music instruction can enhance scientific and technological literacy, particularly through acoustics concepts and ICT-enabled digital tools. Peer-reviewed journal articles, policy documents, and case studies published between 2000 and 2025 were systematically analysed following established review guidelines, with 19 studies meeting the inclusion criteria. The findings reveal that although music is formally embedded within the national curriculum, its interdisciplinary potential for STEAM integration remains underutilised. Key challenges include limited teacher professional development, inadequate ICT infrastructure, curriculum constraints, and insufficient emphasis on scientific principles such as sound waves, frequency, resonance, and vibration. However, innovative practices including digital composition software, virtual acoustics simulations, music-mathematics integration activities, and collaborative cross-disciplinary projects demonstrate positive effects on learner engagement, conceptual understanding, creativity, and problem-solving skills. The review further indicates that structured integration of digital music skills can support inclusive participation and foster critical thinking across artistic and scientific domains. The study concludes that embedding scientific and technological concepts within music education can contribute significantly to holistic learner development and interdisciplinary competence. These findings have implications for curriculum design, teacher training programmes, resource allocation, and education policy, supporting the advancement of contextually responsive STEAM education in South African primary and lower secondary schools.

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1. Introduction

It is prudent to foreground this study by mentioning that music education is widely recognised as a fundamental component of holistic education because it contributes to learners' cognitive, social, linguistic, and cultural development. Existing research demonstrates that music enhances literacy, communication skills, memory retention, and socio-emotional growth, thereby supporting comprehensive learner development (Fuentes et al., 2025; Yende,

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2023). Within the South African context, music education has particular relevance in strengthening reading proficiency and spoken language development, especially in rural and under-resourced schools where innovative and integrative teaching approaches are essential (Yende, 2023). A significant historical turning point occurred in 1994 when South Africa's democratic government committed itself to redressing the educational inequalities created by the apartheid system. Despite these policy reforms, many rural schools continue to experience persistent inequalities in infrastructure, access to learning resources, and technological provision, limiting their ability to implement blended and digitally supported teaching approaches effectively (Mpungose, 2020; Muhuro & Kangethe, 2021). Yende (2021) further notes that inadequate infrastructure, unstable electricity, and weak telecommunication systems in rural South African schools remain direct consequences of apartheid-era policies of segregation and separate development. These historical inequalities continue to shape the quality and accessibility of music education in many schools, particularly in remote communities where specialist resources remain scarce.

In South Africa, the Curriculum and Assessment Policy Statement (CAPS) places music within the Creative Arts subject, yet its implementation often differs substantially between urban and rural schools because of unequal access to specialist teachers, teaching materials, and dedicated classroom spaces. These inequalities have created significant disparities in how music education is experienced by learners across provinces, particularly in historically disadvantaged schools where arts subjects are frequently marginalised in favour of examinable core subjects. As such, music education extends beyond artistic enrichment and functions as a pedagogical tool that supports foundational academic competencies.

In addition to its cognitive and linguistic benefits, music contains measurable scientific and mathematical elements such as pitch, tempo, rhythm, frequency, and dynamics. These components provide natural entry points for interdisciplinary learning. Studies indicate that teachers have successfully integrated music with subjects such as Home Language, Mathematics, and Life Skills, demonstrating its capacity to reinforce conceptual understanding across disciplines (Van Vreden, 2018). Through structured engagement with rhythm patterns, sound properties, and musical structures, learners develop analytical skills and problem-solving abilities that are transferable to scientific and mathematical contexts. For example, the mathematical organisation of rhythm introduces learners to patterns, sequencing, and fractions, while the study of pitch and resonance provides opportunities to explore scientific concepts related to sound production and wave behaviour. This interdisciplinary potential is particularly valuable in South African classrooms where integrated learning can maximise limited instructional time and promote deeper learner engagement across multiple subjects simultaneously. For schools operating under resource constraints, interdisciplinary music teaching may also provide a cost-effective way of strengthening learning across multiple curriculum areas without requiring extensive additional resources.

Interdisciplinary approaches aligned with STEAM (Science, Technology, Engineering, Arts, and Mathematics) education have further highlighted the potential of music as a bridge between artistic creativity and scientific inquiry (Hendriks & Cruywagen, 2024; Semenikhina et al., 2024). Research shows that incorporating music into STEAM curricula enhances critical cognitive skills while fostering collaboration and communication. For example, principles of acoustics and sound physics can be explored through the study of musical instruments, allowing learners to apply theoretical scientific concepts in practical contexts. This integration strengthens both artistic literacy and scientific reasoning by situating abstract knowledge within experiential learning environments. Within South African education, STEAM approaches may offer an important opportunity to reposition music from a peripheral enrichment activity to a meaningful academic discipline that contributes directly to problem-solving, innovation, and critical thinking. Such an approach supports national priorities that seek to improve learner performance in mathematics and science while simultaneously preserving indigenous artistic knowledge and cultural expression within formal schooling. Importantly, the integration of indigenous musical knowledge into STEAM education can create culturally responsive learning experiences that reflect the lived realities of South African learners while supporting inclusive curriculum transformation.

The integration of Information and Communication Technology (ICT) has expanded these possibilities even further. Digital composition tools, virtual instruments, and interactive online platforms enable learners to experiment with sound production, frequency analysis, and musical design in technologically enriched settings (Department of Education, 2011; Hendriks & Cruywagen, 2024; Portero & Bravo, 2022). By combining music with digital technologies,

learners not only enhance their creative capacities but also develop technological literacy and computational thinking skills. Such approaches align music education with the demands of a knowledge-driven and digitally evolving society. However, the successful use of ICT in South African schools remains uneven because many schools continue to experience inadequate internet connectivity, unreliable electricity supply, and insufficient access to digital devices. These infrastructural limitations often prevent teachers from fully integrating digital music technologies into classroom practice despite growing policy emphasis on digital transformation in education. Although national policy frameworks advocate for technology integration in schools, implementation has often been slower in rural provinces where funding limitations and maintenance challenges continue to hinder meaningful classroom innovation. Consequently, while ICT offers transformative possibilities for music teaching, its implementation remains shaped by broader structural inequalities within the education system.

Despite these demonstrated benefits, music education in South African basic schools continues to face significant structural and pedagogical challenges. Limited resource allocation, inadequate teacher training in interdisciplinary methodologies, inconsistent curriculum implementation, and restricted access to ICT infrastructure constrain the effective integration of music with scientific and technological learning (Hendriks & Cruywagen, 2024; Yende, 2023). While the literature acknowledges the potential of STEAM-based music education, there remains insufficient systematic investigation into scalable pedagogical models, structured curriculum alignment, and teacher preparedness for sustained ICT-enabled integration. This gap limits the development of coherent frameworks capable of embedding acoustics, sound physics, and digital technologies within music education in a consistent and transformative manner. Furthermore, many generalist classroom teachers responsible for Creative Arts teaching report limited confidence in music instruction because pre-service teacher education programmes often provide insufficient preparation in both music pedagogy and digital application. This challenge is particularly pronounced in primary schools, where teachers are expected to teach multiple subjects without specialised training in arts integration. As a result, policy intentions frequently remain disconnected from classroom realities, particularly in schools where educational priorities are dominated by survival needs rather than innovation.

This study addresses this gap by systematically reviewing existing research on music education in South African basic schools and evaluating its potential for ICT-enabled STEAM integration and interdisciplinary learning. The objectives of the study are to analyse current implementation practices, identify effective pedagogical strategies, and examine challenges affecting interdisciplinary alignment. The study is guided by the following research questions:

1. How is music education implemented in South African basic schools with respect to ICT and technology integration?
2. What pedagogical strategies support the integration of music with scientific concepts such as acoustics and sound physics?
3. What challenges and gaps exist in aligning music education with interdisciplinary STEAM approaches?
4. How can music education contribute to both artistic development and scientific literacy in learners?

The significance of this research lies in its potential to inform curriculum development, teacher professional development, and education policy reform in South African basic schools. The study positions music education as both an artistic discipline and a means of strengthening scientific inquiry within interdisciplinary learning. It also addresses debates concerning equitable access to arts education and classroom realities in diverse school settings. Attention to historical inequalities in rural schools emphasises the need for contextually responsive interventions that support learners in developing creative, analytical, and technological competencies for contemporary educational environment.

2. Literature Review

2.1 Music Education, Cognitive Development, and Interdisciplinary Foundations

Existing scholarship consistently positions music education as a foundational element of holistic learner development. Research demonstrates that music contributes significantly to cognitive growth, communication skills,

and socio-emotional development across educational contexts. Fuentes et al. (2025, p. 2130) assert that "Music education is recognised as a key component in the comprehensive development of secondary school students, as it enhances cognitive and communicative dimensions while fostering socio-emotional skills in educational contexts." This perspective situates music not merely as an artistic subject, but as an educational catalyst that strengthens multiple dimensions of learning.

Within the South African context, Yende (2023, p. 8) emphasises the role of music in literacy development, stating that "music education is important for reading and helps learners develop significant spoken language proficiency. The approach and analysis in the article were informed by what the researcher views as a nexus that gradually grew in education as a key for effective development for reading and writing, especially in South African rural-based schools." This highlights the particular relevance of music education in rural and under-resourced environments, where integrated approaches can address literacy challenges while fostering inclusive learning. Together, these studies indicate a broader trend in the literature: music education supports not only artistic expression but also language acquisition, reading proficiency, and communicative competence.

Beyond literacy and communication, scholars have also explored the interdisciplinary potential of music. Van Vreden (2018, p. 2) reflects on classroom practice, noting that "the inspiration for this investigation was an event that occurred during data collection for a multiple case study, which was exploring the teaching practices of early childhood teachers to ascertain how they integrate music with Home Language, Mathematics and Life Skills." This finding demonstrates how music can be meaningfully integrated with other subject areas, reinforcing conceptual understanding through experiential engagement. By linking rhythm, pattern, tempo, and pitch to mathematical and linguistic concepts, music becomes a bridge between creative expression and analytical reasoning. The literature therefore reveals a consistent recognition of music as an interdisciplinary medium capable of enhancing both artistic and academic outcomes.

2.2 Music, STEAM Integration, and ICT-Enhanced Learning

A growing body of research situates music education within STEAM (Science, Technology, Engineering, Arts, and Mathematics) frameworks, highlighting its potential to strengthen scientific literacy alongside creativity. Semenikhina et al. (2024, p. 79) argue that the inclusion of music in STEAM curricula is a multifaceted tool that fosters artistic expression while enhancing the critical cognitive skills required for all disciplines. The collaborative nature of music-making encourages teamwork and communication, consistent with Simpson's assertion that creative expression leads to transformative educational experiences. For example, the principles of acoustics in physics can be explored in the study of musical instruments, allowing students to apply theoretical concepts in a practical context. This perspective underscores a key trend in contemporary literature: music provides practical contexts for exploring scientific principles such as acoustics, resonance, and sound waves. Through musical experimentation, learners engage in applied problem-solving and collaborative inquiry, reinforcing both artistic and scientific competencies. Hendriks and Cruywagen (2024) similarly highlight the effectiveness of interdisciplinary strategies in promoting integrated learning experiences that combine analytical reasoning with creative practice. In addition to STEAM integration, ICT has emerged as a transformative factor in music education. Portero and Bravo (2022, p. 11) emphasise that "ICT uses in the music classroom are identified: they improve my teaching practice, encourage methodological instructional development and improve student learning." This aligns with broader findings indicating that digital composition tools, virtual instruments, and interactive platforms enhance engagement and facilitate hands-on exploration of sound properties (Department of Education, 2011).

Van Vreden (2018) further reinforces the scientific dimension of music by highlighting quantifiable elements such as loudness, tempo, and pitch, which enable learners to investigate measurable sound properties within classroom contexts. The integration of ICT tools with these scientific aspects supports interactive experimentation, enabling learners to observe cause-and-effect relationships in real time.

Despite these promising developments, the literature also identifies persistent challenges. Music education in South African basic schools is often constrained by limited resources, insufficient teacher training in interdisciplinary methods, and inconsistent curriculum implementation (Hendriks & Cruywagen, 2024; Yende, 2023). While research

affirms the value of STEAM-based and ICT-enhanced music education, fewer studies provide systematic frameworks for scalable implementation, curriculum alignment, and teacher preparedness. This trend reveals an important gap: the need for structured, evidence-based models that embed acoustics, digital technologies, and interdisciplinary strategies within music education in sustainable ways.

3. Method

This study employed a systematic review design to examine how music education has been integrated with information and communication technology (ICT), acoustics, and science, technology, engineering, arts, and mathematics (STEAM) approaches in South African primary and lower secondary schools. A systematic review was selected because it allows for a structured and transparent synthesis of existing literature, enabling the identification of recurring themes, research gaps, and effective pedagogical practices within a defined body of scholarship (Xiao & Watson, 2017). The review specifically focused on studies that explored the contribution of music education to interdisciplinary learning, scientific literacy, and digital competence in basic education contexts. The South African context was prioritised to ensure the review remained responsive to local curriculum policy, school infrastructure disparities, and teacher preparedness in diverse educational settings.

3.1 Search Strategy

A comprehensive literature search was conducted across multiple academic databases, including Scopus, ERIC, Google Scholar, and South African institutional repositories. The search included peer-reviewed journal articles, conference papers, policy documents, and empirical case studies published between January 2000 and February 2025. Search terms were combined using Boolean operators and included the following keywords: *music education*, *ICT integration*, *acoustics*, *STEAM education*, *interdisciplinary learning*, *creative arts*, and *South African schools*. Additional manual searches of reference lists were conducted to identify relevant studies not captured during the database search. The final search was completed in February 2025, ensuring that the review included the most recent scholarship available at the time of analysis.

3.2 Inclusion and Exclusion Criteria

Studies were selected according to predetermined inclusion and exclusion criteria to ensure consistency during the screening process. Table 1 summarises the criteria applied in the review.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Studies published between 2000 and 2025	Studies published before 2000
Focus on music education in school contexts	Studies focused only on tertiary education
South African basic education context	Studies outside South Africa with no contextual relevance
Empirical or policy-based research	Opinion pieces without evidence
ICT, acoustics, or STEAM integration	Studies unrelated to music education
English-language publications	Non-English publications

Only studies directly addressing the intersection of music education with scientific, technological, or interdisciplinary teaching practices in South African schools were retained for analysis.

3.3 Screening Procedure

The review followed PRISMA guidelines to ensure transparency and reproducibility. A total of 1,656 records were identified through database searching. After removing duplicates and ineligible records, 331 records remained for

title and abstract screening. During this stage, 285 records were excluded, leaving 46 reports sought for retrieval. No reports were lost during retrieval, resulting in 46 reports assessed for eligibility.
At the full-text stage, 24 studies were excluded for the following reasons:

- Not sufficiently relevant (n = 10)
- Not empirical study (n = 9)
- Not directly related to music education (n = 3)
- Insufficient South African contextual relevance (n = 2)

This resulted in a final sample of 22 studies included in the review.

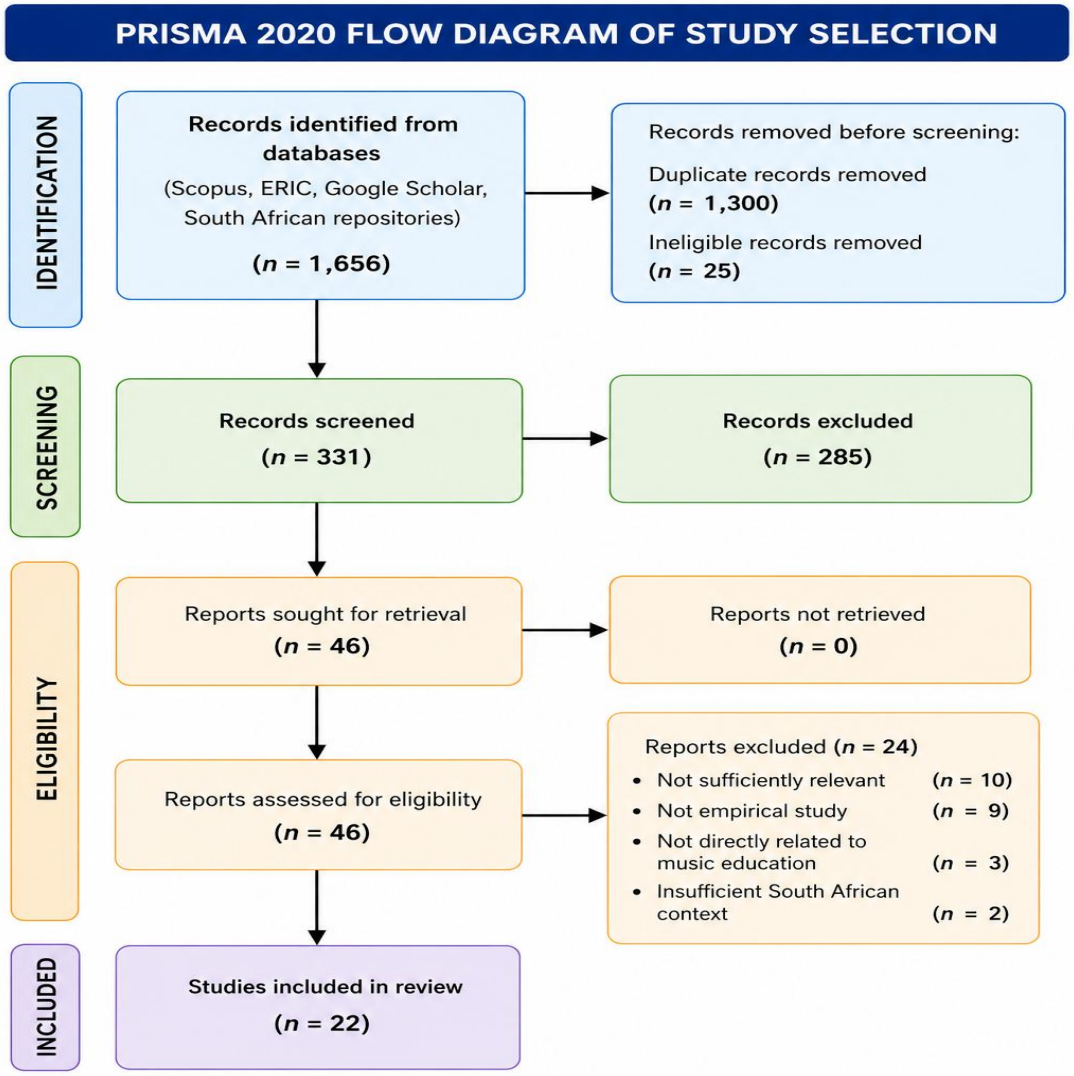

Figure 1: Prisma 2020 Flow Diagram of Study Selection

3.4 Data Extraction

A structured data extraction framework was developed to record relevant information from each included study. Extracted data included publication details, study aims, research design, participant characteristics, educational setting, technological tools used, interdisciplinary strategies, and reported learner outcomes. To improve consistency, each article was reviewed using the same coding framework. Data were then organised into thematic categories to support comparative analysis across studies.

3.5 Data Analysis

The selected studies were analysed using qualitative thematic synthesis. The analysis focused on six key themes:

- ICT-enabled music teaching practices and digital resource utilisation
- Interdisciplinary Pedagogies Connecting Music, Science, and Sound Concepts Systemic
- Barriers to STEAM Integration in School Music Curricula
- Music education as a catalyst for creativity and scientific understanding

Patterns across studies were identified to determine common pedagogical approaches, implementation barriers, and successful practices. Comparative analysis also highlighted differences in technological access and curriculum delivery across school contexts. Triangulation of findings across multiple studies strengthened the credibility and trustworthiness of the review.

3.6 Ethical Considerations

Although this study did not involve human participants, ethical principles were maintained throughout the review process. These included accurate representation of original authors' findings, responsible citation of all sources, transparent reporting of study selection procedures, and adherence to systematic review standards to ensure integrity and reproducibility.

4. Results

This study identified key themes aligned with the research questions, synthesizing findings from 19 included studies. Table 2 summarises the themes derived from literature.

Table 2. Research Questions and Corresponding Themes

Research Questions	Themes
1. How is music education implemented in South African basic schools with respect to ICT and technology integration?	ICT-enabled music teaching practices and digital resource utilisation: Digital tools enhance instruction, enable interactive learning, improve access to resources, and support creativity, collaboration, and inclusive participation (Di Paolo & Todino, 2025; Lam, 2023; Parkita, 2021; Yende, 2024).
2. What pedagogical strategies support the integration of music with scientific concepts such as acoustics and sound physics?	Interdisciplinary pedagogies connecting music, science, and sound concepts: Integrating acoustics concepts through music fosters conceptual understanding, linking artistic expression with scientific inquiry, experimentation, and problem-solving skills (Galea & Ramos, 2024; Qian & Hami, 2025; Van Vreden, 2018).
3. What challenges and gaps exist in aligning music education with interdisciplinary STEAM approaches?	Systemic barriers to STEAM integration in school music curricula: Resource limitations, insufficient teacher training, curriculum constraints, and unequal technological access hinder effective STEAM integration (Nchabeleng, 2025; Seleke et al., 2025; Yende, 2024).
4. How can music education contribute to both artistic development and scientific literacy in learners?	Music education as a catalyst for creativity and scientific understanding: It develops creativity, critical thinking, and scientific literacy, enabling learners to explore patterns, sound properties, and innovative problem-solving approaches (Nchabeleng, 2025; Seleke et al., 2025; Yende, 2024).

4.1. ICT-enabled Music Teaching Practices and Digital Resource Utilisation

Digital tools have increasingly transformed music education by enhancing instructional delivery, fostering interactive learning, and improving access to musical resources for learners. Such tools support creativity, collaboration, and inclusive participation, enabling teachers to create engaging and flexible learning experiences (Di Paolo & Todino,

2025; Lam, 2023; Parkita, 2021). In this study, the use of digital tools and technologies to improve music learning and expression is referred to as 'digital music skills'. These skills encompass learners' ability to manipulate and create music through technology, providing practical, interactive, and creative learning opportunities across a variety of contexts.

For primary school learners, digital music skills can be applied to multiple learning tasks and situations, supporting both cognitive and socio-emotional development (Chomunorwa et al., 2023; Jansen van Rensburg, 2022). Examples of age-appropriate digital music skills include basic music theory applications, virtual instruments, digital composition tools, music listening and appreciation platforms, and digital storytelling through music (Chomunorwa et al., 2023). These applications not only introduce learners to foundational music concepts but also foster higher-order thinking skills such as creativity, critical analysis, and problem-solving. Moreover, digital tools facilitate collaborative activities, allowing learners to co-create music, share performances, and provide peer feedback in ways that traditional methods may not support.

The objectives of this study are threefold. First, it seeks to evaluate the current state of music education in South African primary schools, focusing on the availability and use of digital music skills. Second, it investigates the potential benefits and challenges associated with integrating ICT into music teaching, including issues of access, teacher preparedness, and curriculum alignment. Third, the study aims to provide insights that can guide educational policy and practice, offering recommendations for sustainable implementation of digital music skills in primary school contexts. By understanding how digital tools can enhance music learning, this research contributes to broader goals of fostering interdisciplinary, technology-enabled education that aligns with STEAM principles, promotes creativity, and supports inclusive, learner-centered pedagogies.

4.2. Interdisciplinary Pedagogies Connecting Music, Science, and Sound Concepts

Integrating music with scientific concepts, particularly acoustics and sound physics, fosters deep conceptual understanding by linking artistic expression with scientific inquiry, experimentation, and problem-solving skills (Galea & Ramos, 2024; Qian & Hami, 2025; Van Vreden, 2018). Interdisciplinary approaches in music education encourage learners to explore sound as both a scientific phenomenon and an artistic medium, creating opportunities for experiential learning that engages multiple cognitive domains. For example, Galea and Ramos (2024, p. 4) observe that "creative activities such as soundscape recreation or sound creation, as well as sound experimentation itself, foster creativity in students by allowing them to explore and manipulate sounds in unconventional ways, opening up new avenues for artistic expression and divergent thinking. Soundscape recreation, defined as the process of creating or re-creating specific acoustic environments by manipulating and combining various sound elements, serves multiple pedagogical purposes. It enhances learners' critical listening and auditory discrimination skills while stimulating imagination and creativity through the production of novel auditory experiences. By examining the properties of sound, such as pitch, volume, tempo, and timbre, students develop an understanding of underlying scientific principles, including sound waves, frequency, and resonance. An et al. (2013, p. 2) further emphasise the interdisciplinary potential of music, stating that "in regard to the first point, music can be used to engage students in learning mathematics in an enjoyable but also relevant way. Secondly, music can be used as a resource by teachers to present and design mathematical problems in non-routine ways. This provides students with the opportunity to apply their mathematical knowledge in meaningful ways and connect new mathematical knowledge to existing knowledge.

Such examples illustrate how music can be leveraged as a bridge between artistic and scientific learning. Integrating mathematics and acoustics into music activities allows learners to apply theoretical concepts in practical contexts, reinforcing problem-solving skills, critical thinking, and conceptual transfer across disciplines. Interdisciplinary music practices not only enhance scientific literacy but also promote creativity, collaboration, and engagement by enabling students to experiment, hypothesise, and reflect on their learning outcomes. The overarching goal of this study is to investigate how interdisciplinary pedagogical approaches in South African basic schools can connect music with scientific concepts, fostering both artistic growth and scientific understanding. By examining the integration of acoustics, sound physics, and related STEAM concepts in music lessons, the research seeks to inform teaching practices, curriculum development, and educational policy aimed at promoting holistic, experiential, and technology-enhanced learning in primary and lower secondary school contexts.

4.3. Systemic Barriers to STEAM Integration in School Music Curricula

The integration of STEAM principles, including ICT and scientific concepts, into school music curricula faces multiple systemic barriers that hinder effective implementation (Nchabeleng, 2025; Seleke et al., 2025; Yende, 2024). These challenges require deliberate planning, strategic interventions, and collaborative efforts from educators, policymakers, and stakeholders to ensure equitable access and meaningful learning experiences. Many of these obstacles are rooted in historical inequities established during the apartheid era, which created deep divides in educational opportunities, particularly between urban and rural schools (Nchabeleng, 2025). Consequently, learners in under-resourced areas often experience limited exposure to technology, music resources, and interdisciplinary STEAM activities.

One of the most prominent challenges is the digital divide, which reflects socioeconomic disparities that affect students' access to ICT tools, digital music applications, and online learning resources. Yende (2024, p. 4) emphasises that this gap exacerbates inequalities, as learners from disadvantaged backgrounds are less likely to benefit from digital-enhanced music instruction. Similarly, many educators face difficulties in adopting STEAM approaches due to limited technical proficiency, insufficient professional development, and apprehension about deviating from conventional teaching methods. Resistance from both teachers and school stakeholders can therefore slow the adoption of innovative, technology-based pedagogies.

Resource limitations further constrain the integration of STEAM into music education. Public schools often struggle to acquire, maintain, and update essential hardware, software, and infrastructure required for digital music activities, virtual instruments, and interactive learning platforms (Seleke et al., 2025). Inadequate funding and inconsistent policy support exacerbate these issues, leading to fragmented or partial implementation of interdisciplinary approaches. Curriculum constraints also pose a significant barrier. The traditional focus on rote learning and examination-driven outcomes often limits opportunities for experimental, collaborative, and inquiry-based music activities that incorporate science, mathematics, and technology. As a result, the potential of music education to enhance both artistic and scientific literacy remains underutilised.

Addressing these systemic barriers requires coordinated interventions, including targeted teacher training, investment in ICT infrastructure, and curriculum redesign to support interdisciplinary STEAM learning. Recognising and mitigating the historical, socioeconomic, and institutional factors that impede equitable access is critical for fostering inclusive, technology-enabled music education in South African schools. By confronting these challenges, educators and policymakers can create conditions that allow music education to fulfill its potential as a platform for creativity, critical thinking, and scientific exploration.

4.4. Music education as a catalyst for creativity and scientific understanding

Music education in South African schools serves as a powerful tool for fostering creativity, critical thinking, and scientific literacy. Engaging with music allows learners to recognise patterns, experiment with sound properties, and develop innovative problem-solving skills, bridging artistic expression with analytical reasoning (Hendriks & Cruywagen, 2024; Semenikhina et al., 2024; Van Vreden, 2018). By interacting with diverse musical experiences, students cultivate both cognitive and creative abilities, enhancing their capacity to connect artistic learning with broader scientific and technological concepts. Van Vreden (2018, p. 5) highlights that children's musical play is central to developing musical competence and understanding. Access to instruments and learning resources encourages exploration, improvisation, and creation, strengthening both technical musical skills and cognitive engagement. Early childhood educators can further enrich this process by intentionally integrating music into daily classroom routines, ensuring that musical knowledge, skills, and experiences become a consistent and meaningful part of learners' educational journey.

Practical music activities including singing, body percussion, movement-based exercises, instrumental play, improvisation, and music composition contribute to learners' holistic development (Nkosi, 2025; Van Vreden, 2018). These activities not only cultivate technical skills, such as sight reading and notation, but also enhance critical listening, pattern recognition, and problem-solving abilities. Providing learners with opportunities to make independent musical decisions, guided by educators with strong pedagogical knowledge, nurtures innate musicality while reinforcing scientific concepts such as sound waves, resonance, and rhythm.

Furthermore, music education offers a natural platform for interdisciplinary learning and STEAM integration. Rhythm patterns can be linked to mathematical sequences, sound experiments can illustrate physics principles, and collaborative music-making fosters communication and teamwork (Hendriks & Cruywagen, 2024; Semenikhina et al., 2024). By merging artistic expression with analytical thinking, music lessons cultivate versatile learners who can apply creative solutions to complex problems. Integrating music into school curricula thus promotes cognitive growth, imaginative exploration, and scientific understanding, positioning music as both an artistic and educational catalyst for holistic student development.

5. Discussion

This study demonstrates that music education in South African basic schools has significant potential as a tool for fostering creativity, critical thinking, and scientific literacy when integrated with ICT and STEAM-based approaches. The findings indicate that despite these benefits, systemic and contextual barriers continue to constrain effective implementation. Rather than viewing music as an isolated creative subject, the findings suggest that music can function as a pedagogical bridge between artistic learning and scientific understanding in ways that respond to the broader educational needs of South African schools. This means that music education should not only be understood as cultural enrichment but also as a meaningful contributor to interdisciplinary teaching that can strengthen learner participation across multiple curriculum areas.

Integration of digital music skills through virtual instruments, composition software, music theory applications, and interactive platforms enhances learner engagement, collaboration, and inclusive participation. Consistent with previous research (Di Paolo & Todino, 2025; Lam, 2023; Parkita, 2021), this study confirms that access to digital resources supports creativity and problem-solving while reinforcing learners' understanding of musical and scientific concepts. Learners who engage with digital tools develop both technical musical abilities and analytical skills that can be applied across disciplines, facilitating interdisciplinary learning. Within the South African context, these findings indicate that ICT-supported music education can create alternative learning opportunities for schools where conventional resources such as instruments and specialist teachers may be limited. Digital platforms can therefore reduce some barriers to participation by enabling learners to explore music through accessible technological environments, particularly where physical resources are unavailable. However, the findings also show that the benefits of technology are dependent on the availability of stable infrastructure, which remains uneven across many South African schools.

Interdisciplinary pedagogical approaches linking music with scientific concepts, such as acoustics, sound properties, and mathematical patterns, foster deeper conceptual understanding. These findings align with Galea and Ramos (2024) and An et al. (2013), who emphasise that activities such as soundscape creation, musical experimentation, and music-mathematics integration promote both creative expression and cognitive development. Van Vreden (2018) further highlights that structured musical play, instrumental activities, and improvisation enhance auditory discrimination, pattern recognition, and problem-solving skills. This study confirms that when learners are given autonomy and supported by educators with strong pedagogical knowledge, musicality develops alongside scientific literacy. Hendriks and Cruywagen (2024) similarly note that interdisciplinary music practices connect artistic exploration with analytical reasoning, contributing to STEAM learning. The significance of these findings lies in the possibility that music can make abstract scientific concepts more concrete for younger learners through embodied and experiential learning. For example, rhythm can help explain mathematical sequencing, while vibration and pitch can help learners understand sound physics in ways that traditional teaching methods may not achieve as effectively. This suggests that music education can deepen conceptual understanding rather than simply supplementing other subjects.

Despite these advantages, several systemic barriers hinder consistent implementation. Limited technological infrastructure, insufficient teacher training, and socioeconomic disparities continue to affect equitable access to ICT-enabled music instruction. These challenges align with the findings of Nchabeleng (2025) and Yende (2024), which highlight the enduring effects of historical inequities and the digital divide in South African schools. Addressing these barriers requires deliberate interventions, including targeted professional development, equitable allocation of resources, and curriculum reforms that support interdisciplinary STEAM learning through music. The findings indicate

that policy support alone is insufficient unless schools receive practical assistance that enables teachers to translate curriculum expectations into classroom practice. Many schools continue to operate under conditions where overcrowding, limited electricity, and inadequate internet access make sustained ICT integration difficult, particularly in rural communities. As a result, the promise of digitally supported music education remains unevenly distributed across the schooling system.

The study also highlights the importance of teacher preparedness in determining whether interdisciplinary music education can be implemented successfully. Teachers who possess both musical confidence and technological competence are better positioned to create meaningful STEAM learning experiences. This suggests that teacher education programmes should move beyond traditional subject boundaries and prepare educators to teach music as part of integrated learning rather than as a stand-alone activity. Professional development initiatives should therefore focus not only on digital tools but also on helping teachers understand how musical activities can support scientific inquiry, collaboration, and critical thinking. Without such preparation, teachers may continue to rely on conventional approaches that limit the transformative potential of music education in the classroom.

The findings suggest that music education can serve as a catalyst for both artistic and scientific development, enhancing creativity, collaborative skills, and analytical thinking when supported by adequate resources, teacher training, and inclusive pedagogical strategies. Practical music activities such as singing, movement-based exercises, instrumental play, improvisation, and composition foster holistic development, linking musical learning with scientific inquiry. Rhythm patterns can illustrate mathematical sequences, sound experiments can demonstrate physics principles, and collaborative music-making encourages communication and teamwork (Hendriks & Cruywagen, 2024; Semenikhina et al., 2024; Van Vreden, 2018). These findings reinforce the argument that music education can contribute to learner development in ways that extend beyond performance skills and support broader educational transformation in South African schools.

Future research could investigate scalable ICT-enabled music instruction models, longitudinal impacts of interdisciplinary STEAM integration, and innovative assessment strategies to measure both creative and scientific learning outcomes. Further research should also examine how rural schools can adapt low-cost technological solutions to support music learning under constrained conditions. By addressing structural, pedagogical, and technological challenges, music education can fully realise its potential as an interdisciplinary learning platform, bridging the arts and sciences and equipping learners with essential skills for holistic development.

6. Conclusion

This systematic review found that music education in South African basic schools can support creativity, scientific literacy, and interdisciplinary learning when integrated with ICT and STEAM-based teaching. The findings show that digital music tools and interdisciplinary classroom practices can strengthen learner engagement, collaboration, and conceptual understanding. However, the review also identified persistent barriers, including limited infrastructure, inadequate teacher preparation, and unequal access to technological resources, which continue to restrict effective implementation in many schools.

The contribution of this study lies in demonstrating that music education can function not only as an artistic subject but also as a meaningful platform for connecting creative practice with scientific and technological learning. The review further highlights the importance of understanding music education within the realities of South African schooling, where historical inequalities continue to influence access and implementation.

For educators, the findings suggest the need to adopt teaching strategies that intentionally connect music with scientific concepts and digital learning. For policymakers, the study emphasises the importance of curriculum support, targeted teacher development, and improved resource allocation to strengthen interdisciplinary music education. Greater policy attention to rural and under-resourced schools is essential if music education is to become more equitable across the basic education system.

Future research should examine scalable models of ICT-supported music teaching, long-term learner outcomes, and assessment approaches that capture both creative and cognitive development. Further studies should also explore contextually appropriate technological solutions that can support music education in schools with limited infrastructure. Such research can strengthen evidence-based practice and support the continued development of music education in South African schools.

Declarations

Competing Interests
None.

Ethical Approval
This study was granted an exemption from requiring formal ethics approval, as it does not involve human participants or the collection of sensitive personal data. The research employed a systematic review methodology, utilising secondary data exclusively from academic databases such as Scopus, ERIC, Google Scholar, and South African education repositories. Accordingly, the study adheres to institutional guidelines that classify this type of research as low-risk and not subject to formal ethics approval. All procedures were conducted in accordance with standard academic and research integrity practices.

Author's Contribution
Author[1]: Sakhiseni Joseph Yende was solely responsible for all aspects of the study, including conceptualisation, methodology design, data curation, formal analysis, and investigation. The author also managed resources and software, conducted validation and visualisation of results, and prepared the manuscript, including writing the original draft, reviewing, and editing. Supervision of the research process was undertaken entirely by the author.

Data availability
All data generated or analysed during this study are included in this published article and its referenced sources. As this research is based exclusively on secondary data from publicly accessible databases and published literature, no additional datasets were created or are required for replication.

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