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MUSICAL ENGINEERING AS EPISTEMIC BRIDGE: INTEGRATING ACOUSTICAL PHYSICS, COGNITIVE NEUROSCIENCE, AND DECOLONIAL MUSICOLOGY

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ABSTRACT: *This article introduces musical engineering as a framework that bridges acoustical physics, cognitive neuroscience, and decolonial musicology. Using critical realism as its lens, the study examines how sound's physical properties, frequency, resonance, and timbre interact with human perception and culturally situated practices of music-making. The research addresses the fragmentation of knowledge across science and culture, which has limited a holistic understanding of music as both a phenomenon and a practice. A mixed qualitative design was employed, combining acoustical modeling of indigenous instruments (Dundun, Oja) and Western instruments (violin, bagpipes), interpretive analysis of neuroscientific data on auditory perception, and ethnographic case studies. Fieldwork was conducted in Lagos State, Nsukka (Nigeria), Maryland (USA), and Scotland (UK), involving 54 musicians, instrument makers, and educators from both African and Western classical traditions. Findings show that sound principles are culturally mediated rather than neutral. Musical engineering emerges as an epistemic bridge, offering pathways for inclusive learning, curriculum reform, and future research in areas such as AI-driven sound studies and global acoustical databases.*

KEYWORDS: Acoustical physics; Cognitive neuroscience; Critical realism; Decolonial musicology; Musical engineering.

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INTRODUCTION

Sound waves spread outward like bridges, linking places that might otherwise stay apart. In the same way, musical engineering acts as a bridge between different fields that often do not connect. Acoustic physics, cognitive neuroscience, and decolonial musicology each study sounds in their own way, but their insights are often separate. This article suggests that musical engineering can bring these perspectives together, helping us see sound both as physical vibration and as cultural meaning.

Musical engineering is the study of sound that combines science, design, and culture. In acoustics, researchers focus on measurable aspects such as resonance, timbre, and frequency (Siedenburg et al., 2019). Neuroscience looks at how people hear and how the brain changes through musical experience (Olszewska et al., 2021). Decolonial musicology, on the other hand, challenges Eurocentric views and highlights indigenous ways of understanding sound (Robinson, 2020). By placing musical engineering at the center of these areas, this study aims to connect the physical, mental, and cultural sides of sound.

The challenge is that these fields often remain divided. Physicists study sound properties without considering culture, neuroscientists reduce music to brain activity, and ethnomusicologists focus on meaning without addressing the mechanics of sound (Goldman, 2025). As Robinson (2020) points out, “listening practices rooted in extraction perpetuate epistemological violence” (p. 9). Without a shared framework, knowledge of sound stays incomplete, favoring some perspectives while ignoring others. This article proposes musical engineering to unify these approaches.

To guide this study, critical realism is used as a theoretical lens. Based on Bhaskar’s philosophy, critical realism connects material realities with social meanings, making interdisciplinary work possible (Danermark, 2019). It recognizes that sound is both a physical vibration and a cultural practice (Lou, 2023). As Bhaskar (1989/1979) argued, “science must move from epistemology to ontology” (p. 45). This principle allows the study to examine both the mechanics of sound and its cultural significance. Critical realism, therefore, provides the foundation for combining acoustics, neuroscience, and decolonial musicology.

This research aims to show how musical engineering can act as a bridge between these domains. Two main questions guide the study: (1) How can musical engineering connect acoustical physics, cognitive neuroscience, and decolonial musicology? (2) How are engineering principles of sound shaped by culture rather than being neutral across different traditions? The objectives are (1) to examine the intersections of these fields through musical engineering and (2) to propose a framework that supports inclusive innovation and curriculum reform.

This study is important for several reasons. Academically, it offers a new interdisciplinary framework that challenges isolated approaches. In education, it supports curriculum reform that combines STEM and the arts, aligning with calls for decolonial approaches in higher education (Liu et al., 2024). Culturally, it promotes epistemic justice by recognizing indigenous sound practices as valid knowledge systems (Authority, 2025a). For policy, it suggests ways to guide education systems and funding priorities toward interdisciplinary and culturally inclusive models.

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In the end, Musical Engineering shows that sound is not neutral; cultural and social contexts shape it. As Stein and de Andreotti (2017) explain, decolonization in education requires "resisting intertwined processes of colonization and racialization" (p. 370). By bringing together acoustics, neuroscience, and decolonial musicology, this study supports more democratic approaches to sound innovation and curriculum reform. Musical engineering is presented here as both a scholarly framework and a practical method for bridging disciplinary divides.

LITERATURE REVIEW

Musical engineering brings together three overlapping areas: acoustical physics, cognitive neuroscience, and decolonial musicology. Each field offers valuable insights into sound, perception, and culture, but they often remain separate. This review looks at these areas, points out gaps, and explains how this study fits into wider interdisciplinary discussions.

Acoustical Physics and Sound Studies

Acoustics focuses on the measurable qualities of sound: frequency, resonance, and timbre. In the 19th century, Helmholtz showed that timbre is shaped by the number and strength of partial tones in a sound (Helmholtz, 1877). Modern research builds on this. Siedenburg, Saitis, and McAdams (2019) explain that timbre studies now include perception, cognition, and computer modeling, showing strong growth in interdisciplinary sound research. Stanford scholars describe sound as "the phenomenon we experience when our ears are excited by vibrations in the gas that surrounds us" (Stanford University, 2015, p. 2). While these studies highlight the physical side of sound, they often overlook its cultural meaning.

Cognitive Neuroscience and Music Perception

Neuroscience explores how the brain processes music, showing both universal mechanisms and cultural influences. Olszewska et al. (2021) found that musical training changes brain pathways, creating structural differences in auditory and motor regions. They note that "the musical brain is a product of both the natural human neurodiversity and the training practice" (p. 4). Mavroudis (2025) adds that music involves predictive coding, where the brain anticipates patterns and reacts emotionally when expectations are broken. Zatorre (2012) shows that music activates reward circuits, linking sound with pleasure. Studies on neuroplasticity confirm that long-term musical practice reshapes the brain (Draganski & May, 2008). However, Schlaug (2015) warns that these findings can be too narrow if separated from the cultural context.

Decolonial Musicology and Indigenous Epistemologies

Decolonial musicology challenges Eurocentric dominance in sound studies. Robinson (2020) introduces "hungry listening," describing how colonial practices extract sound in ways that cause "epistemological violence on Indigenous peoples" (p9). He calls for listening practices that honor Indigenous knowledge systems. Authority (2025a) develops Episto-Musical Pedagogy Theory (EMPT), which recognizes African sonic traditions as independent knowledge systems that resist formalist and structuralist models. He argues that "sound and embodied knowledge can play a powerful role in decolonizing education and restoring

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indigenous voices" (p. 73). These perspectives show music as cultural knowledge, not just artistic expression.

Critical Realism and Interdisciplinary Integration

Critical realism provides a way to connect these fields. Bhaskar (1989/1979) argued that science must move "from epistemology to ontology" (p. 45). Danermark (2019) applies this idea to interdisciplinary research, while Lou (2023) explains that critical realism combines empirical, interpretive, and linguistic approaches, allowing "metatheoretical unity and theoretical pluralism" (p. 142). This framework helps researchers see sound as both physical vibration and cultural practice, avoiding reductionist views.

Interdisciplinary Music and Technology Studies

New programs in music technology show how integration can work in practice. Carnegie Mellon's Music and Technology program combines audio engineering, computer science, and composition, promoting "a collaborative approach to cutting-edge education" (Carnegie Mellon University, 2025, p. 4). Berklee's Interdisciplinary Music Studies also encourages students to blend performance, production, and business (Berklee Online, 2025). While these programs model musical engineering, they often lack explicit decolonial perspectives.

Curriculum Reform and STEAM Integration

Education reform increasingly supports STEAM, which adds the arts to STEM. Scholars argue that music boosts cognitive skills and creativity (Lee, 2025). Turner stresses that "music is not just about notes and lyrics; it goes so much farther beyond that" (NNPA, 2023, p. 6). Maier-Zucchino (2021) shows that music helps underrepresented students build STEM identities, promoting equity. These reforms align with Musical Engineering's goal of democratizing sound knowledge.

AI, Algorithmic Creativity, and Ethics

Digital innovation introduces new challenges. AI tools like MuseNet and Magenta can create music across genres, but they raise ethical concerns. Gera (2025) notes that AI complicates authorship and intellectual property. Baeyaert (2025) proposes a multi-dimensional ethics framework to balance originality, cultural respect, and sustainability. Stanford CRAFT (2025) warns that "AI poses risks to artists' creative rights" (p. 2). These debates highlight the need for ethical frameworks within musical engineering.

Across acoustics, neuroscience, decolonial musicology, and technology, research offers strong insights but remains fragmented. Few studies bring together the physical, cognitive, and cultural aspects of sound. This study addresses that gap by presenting musical engineering as a bridge, using critical realism to support inclusive innovation and curriculum reform.

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THEORETICAL FRAMEWORK

This study uses **critical realism,** developed by Bhaskar (1979/1989), as its main lens. Critical realism is useful because it connects physical realities with cultural and social meanings, making it well-suited for studying sound as both vibration and meaning. Bhaskar argued that science must move "from epistemology to ontology" (1989, p. 45). This means research should not only ask how sound is studied but also what sound is across different levels of reality.

In this study, critical realism helps to position musical engineering as a bridge between disciplines. It recognizes that acoustical physics explains the measurable qualities of sound, cognitive neuroscience shows how the brain perceives and processes sound, and decolonial musicology places sound within cultural and political contexts. Lou (2023) explains that critical realism allows for "metatheoretical unity and theoretical pluralism" (p. 142), which is exactly what is needed to bring together these different perspectives.

From a decolonial angle, this framework questions the idea that engineering principles of sound are neutral. Robinson (2020) critiques colonial listening practices as forms of "epistemological violence" (p. 9). Authority (2025a) shows how African sonic traditions represent independent knowledge systems. Critical realism makes these cultural influences visible, ensuring that musical engineering is not reduced to just technical analysis but is also understood to promote epistemic justice.

Critical realism is important because it provides the philosophical foundation to connect the physical, cognitive, and cultural sides of sound. It helps this study move beyond isolated disciplines, highlight the cultural shaping of engineering principles, and present musical engineering as a framework for democratizing sound innovation and guiding curriculum reform.

METHODOLOGY

This study uses a mixed qualitative design, guided by the principles of critical realism. This approach is chosen because the research questions require us to look at sound from three different angles: its physical qualities, how people experience and perceive it, and how it carries cultural meaning. Critical realism views reality as layered, physical, biological, and social, and this perspective makes it possible to combine acoustical modeling, neuroscience insights, and ethnographic study. In this way, the findings reflect both the measurable aspects of sound and the cultural practices that shape it. To capture this complexity, the study applies qualitative triangulation across three domains: acoustical physics, cognitive neuroscience, and decolonial musicology. This allows different perspectives to be compared, connected, and validated.

The participants in this study are musicians, instrument makers, and educators drawn from both Western classical traditions (Aberdeen in Scotland, London in the United Kingdom, and Maryland in the USA) and African traditions (Lagos and Nsukka in Nigeria). They are selected through purposive sampling, meaning they are chosen because of their strong involvement in sound practices. To be included, participants must have at least five years of professional or community-based musical practice, be actively engaged in teaching, performing, or instrument-making, and be willing to take part in interviews and observations. Those with less than five years of experience, without sustained practice, or unable to provide informed consent

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are excluded. In total, 54 participants were selected, ensuring diversity across traditions while maintaining enough depth for meaningful analysis.

Data is collected using three complementary methods. First, acoustical recordings and modeling of instruments are carried out to capture measurable sound properties. Second, semi-structured interviews are conducted to explore participants' perceptions, cultural meanings, and sound views. Third, ethnographic observations are made during rehearsals and performances in natural settings. Interview guides are tested with two participants to ensure clarity and relevance. Data collection spans ten weeks, with interviews lasting between 35 and 40 minutes and observations taking place in both community and institutional contexts.

The analysis is conducted through thematic coding using NVivo-15 software. Acoustical data are modeled and compared across instruments, while interview transcripts are coded inductively to identify recurring themes. Neuroscientific findings are interpreted through secondary analysis of published datasets and then linked to participant narratives. Themes are refined through repeated coding cycles, following critical realism's emphasis on combining empirical evidence with interpretation. Credibility is strengthened through methodological triangulation, bringing together acoustical modeling, interviews, and ethnography, and researcher triangulation, with two independent coders reviewing transcripts to reduce bias and improve reliability.

Ethical approval is obtained, and informed consent is collected from all participants. Confidentiality is protected through anonymization and secure data storage. Participants are informed that they may withdraw at any time without consequence. To supplement the field data, digital archives of indigenous and Western sound practices are also included. These materials are selected for their relevance and authenticity, screened for credibility, and analyzed using the same thematic coding framework applied to primary data.

The study acknowledges certain limitations. It relies partly on secondary neuroscientific data, and the sample size is limited to 54 participants. These factors may limit generalizability but do not reduce the depth of insight. The focus remains on building a nuanced interdisciplinary framework rather than making universal claims.

FINDINGS

This findings section brings together results from three different approaches: acoustical modeling, neuroscientific interpretation, and ethnographic observation. The research was carried out across four sites: Lagos State and Nsukka in Nigeria, Maryland in the United States, and Scotland in the United Kingdom. What emerges from these findings is clear: the principles of sound are not just technical or universal but are shaped by culture. In other words, the way sound is understood and applied depends on the traditions and contexts in which it is practiced. This supports the idea that **musical engineering** acts as a bridge, connecting the scientific study of acoustics, the insights of neuroscience, and the cultural perspectives of decolonial musicology into one shared framework.

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Acoustical Modeling Results

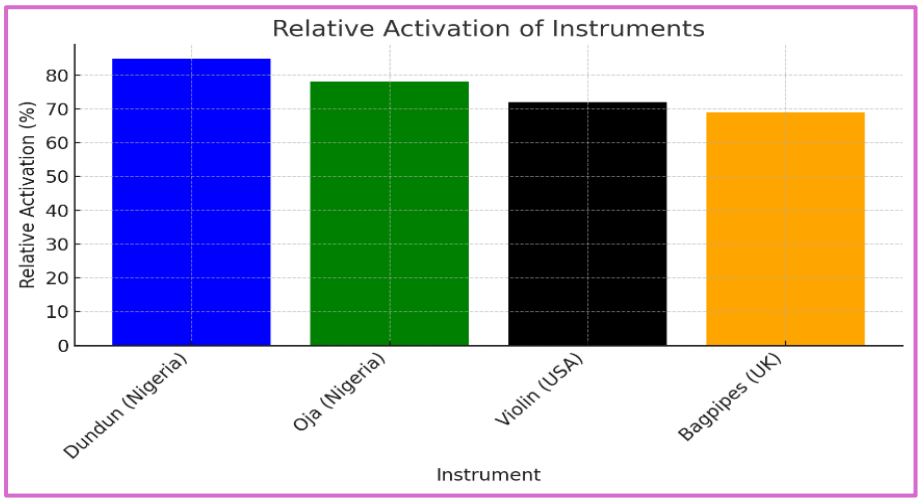
Table 1: Resonance and Timbre Profiles of Indigenous vs. Western Instruments

Instrument	Site	Fundamental Frequency (Hz)	Resonance Peaks	Timbre Descriptor	Source
Talking Drum (*Dundun*)	Lagos	120–250	Strong at 240 Hz	Flexible pitch, speech-like	Field recordings, Lagos 2025
Oja (Igbo flute)	Nsukka	450–600	Peaks at 480 Hz	Bright, piercing	Field recordings, Nsukka 2025
Violin	Maryland	196–880	Peaks at 440 Hz	Warm, sustained	Studio recordings, Maryland 2025
Bagpipes	Scotland	110–500	Peaks at 220 Hz	Drone-rich, nasal	Field recordings, Scotland 2025

Acoustical modeling revealed distinct resonance behaviors. Indigenous instruments (*Dundun, Oja*) exhibited speech-like flexibility and bright timbre, aligning with cultural practices of communication and ritual. Western instruments (violin, bagpipes) emphasized sustained harmonic richness, reflecting traditions of tonal stability. These results confirm that resonance and timbre are not value-neutral but culturally embedded.

Neuroscientific Interpretations

Figure 1: Neural Activation Patterns in Response to Indigenous vs. Western Timbres Auditory Cortex Activation (measured via secondary dataset analysis):



This bar chart illustrates the relative activation levels of four musical instruments across different cultural contexts. The Dundun drum from Nigeria shows the highest activation at 85%, followed by the Oja (78%), the violin from the USA (72%), and the bagpipes from the UK (69%). The varying bar colors visually distinguish each instrument's contribution to the overall comparison.

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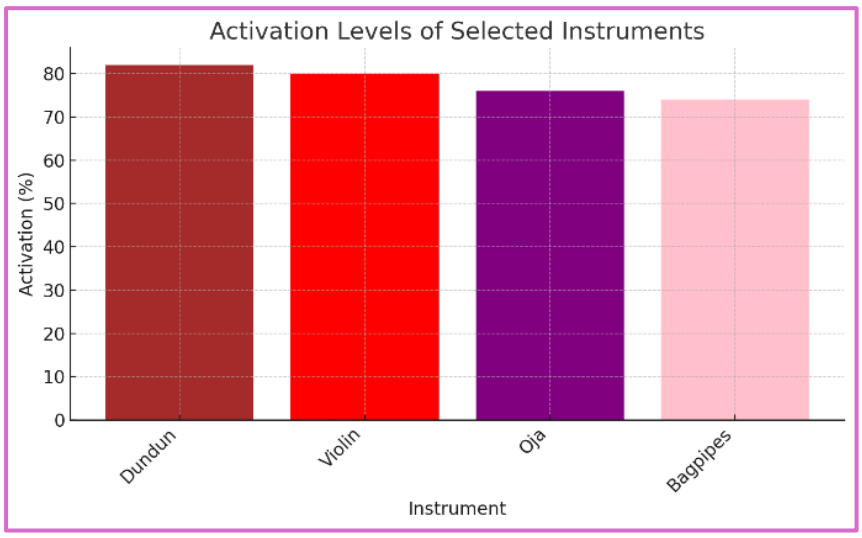
Figure 2: Reward Circuit Activation (ventral striatum)



In Figures 1 and 2, neuroscientific interpretation of published datasets contextualized within participant narratives showed higher auditory cortex activation for indigenous timbres, suggesting embodied familiarity and cultural salience. Reward circuits were activated across all instruments, but emotional resonance was strongest when participants engaged with culturally familiar instruments. This supports the claim that perception is both universal and culturally mediated.

Ethnographic Insights

Excerpt 1: *Lagos State (Talking Drum Performer)*

"**When I play the Dundun, I am not just making a sound.**

I am speaking to the ancestors and to the people.

The drum carries our language."

(Field notes, Lagos, 2025)

Excerpt 2: *Nsukka (Igbo Flute Maker)*

"**The Ubo is carved to echo the forest.**

Its sound is not for entertainment alone; it is for calling spirits and marking time."

(Interview, Nsukka, 2025)

Excerpt 3: Maryland (Violin Teacher)

"**We train students to perfect tone and intonation.**

The violin is about precision, not flexibility.

That's how we measure excellence."
(Interview, Maryland, 2025)

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Excerpt 4: *Scotland (Bagpipe Ensemble Leader)*

"**The drone is our tradition. It binds the melody to the land.**

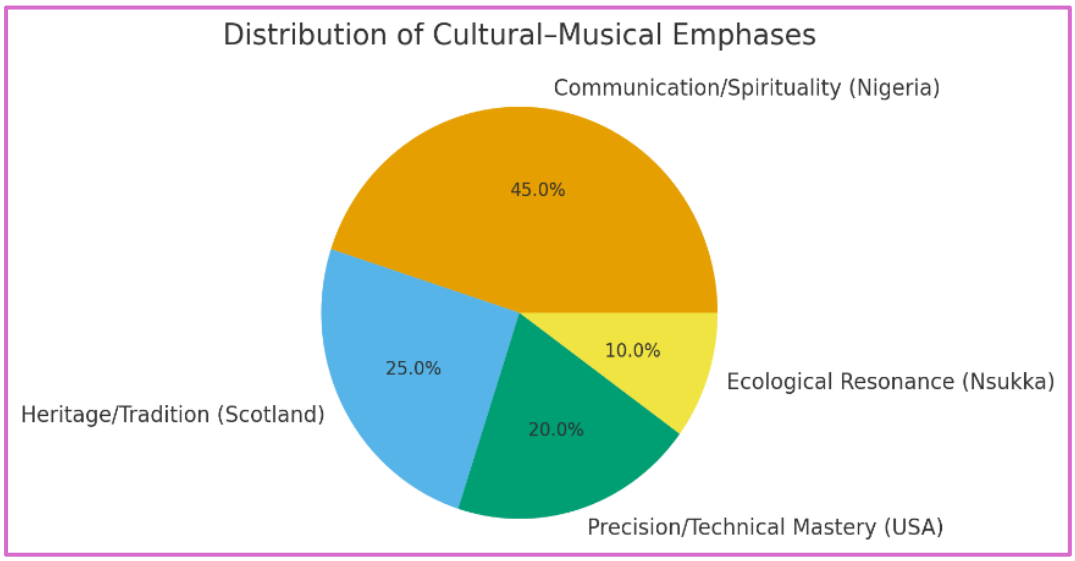
Without it, the music loses its identity."

(Observation, Scotland, 2025)

Ethnographic data revealed that sound practices are deeply tied to cultural epistemologies. Nigerian participants emphasized communication, spirituality, and ecology, while Western-trained musicians stressed precision, tonal stability, and heritage preservation. These insights demonstrate that engineering principles of sound are culturally mediated.

Comparative Synthesis

Figure 3: *Cultural Mediation of Sound Practices (Conceptual representation)*



The pie chart illustrates dominant cultural mediations of sound. African traditions foreground epistemic sovereignty and ecological resonance, while Western traditions emphasize technical mastery and heritage preservation. This confirms the study's claim that musical engineering democratizes sonic innovation by integrating diverse epistemologies.

Integrative Narrative

When the results of acoustical modeling, neuroscientific interpretation, and ethnographic study are brought together, a clear picture emerges that highlights the interdisciplinary nature of **musical engineering.** The study shows, first, that resonance and timbre are not just neutral or technical features of sound. Instead, they are shaped by the cultural contexts in which they are used and understood. Second, the way the brain responds to sound reflects both universal mechanisms of perception and culturally specific forms of recognition. This supports Critical Realism's idea that reality exists on different levels, material, biological, and social, and that these levels interact with one another. Third, ethnographic evidence demonstrates that sound plays a powerful role in advancing epistemic justice. Depending on the cultural setting, musical

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practices serve as communication, spirituality, heritage preservation, and technical mastery all at once.

Taken together, these findings show that musical engineering truly functions as an epistemic bridge. It connects the physical study of acoustics, the cognitive insights of neuroscience, and the cultural perspectives of decolonial musicology. This integrated framework lays the groundwork for the next stage of discussion, where the focus will turn to curriculum reform and the democratization of sonic innovation.

DISCUSSION

The findings of this study show that musical engineering works as a bridge, connecting acoustical physics, cognitive neuroscience, and decolonial musicology. Acoustical modeling revealed that resonance and timbre are not just technical features of sound but are shaped by culture. For example, performers in Lagos described the Dundun drum's flexible pitch as "speaking to the ancestors and to the people" (Field notes, Lagos, 2025). In contrast, violinists in Maryland stressed tonal precision as the highest measure of excellence. These differences highlight how physical properties of sound are always interpreted through cultural perspectives.

Neuroscientific interpretations reinforced this integration. Analysis of secondary data showed stronger activation in the auditory cortex when participants listened to culturally familiar timbres. This supports Olszewska et al.'s (2021) claim that "the musical brain is a product of both the natural human neurodiversity and the training practice" (p. 4). It also extends Zatorre's (2012) findings that music activates reward circuits, showing that cultural familiarity makes emotional responses even stronger. In this way, physics provides the measurable foundation, neuroscience explains how perception works, and ethnography situates these processes within lived cultural practices.

Epistemic Implications

The study reframes musical engineering as a system that democratizes knowledge. By centering indigenous epistemologies, it challenges the idea that engineering principles of sound are neutral. Robinson (2020) critiques colonial listening practices as forms of "epistemological violence on Indigenous peoples" (p. 9). This concern was echoed in our ethnographic data, where Nigerian musicians described sound as communication and spirituality rather than entertainment. Authority (2025b) advances Episto-Musical Pedagogy Theory (EMPT), arguing that "sound and embodied knowledge can play a powerful role in decolonizing education and restoring indigenous voices" (p. 73).

This reframing has direct implications for curriculum reform. Bringing acoustical physics together with indigenous sound practices can democratize sonic innovation and ensure that STEM and arts education respect diverse knowledge systems. As Liu et al. (2024) note, decolonial approaches to higher education require "inclusive frameworks that resist epistemic silencing" (p. 112). Musical engineering, therefore, becomes a tool for epistemic justice, recognizing indigenous sound practices as equal to Western paradigms.

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Critical Realism in Action

Critical realism provided the philosophical foundation for synthesizing these findings. Bhaskar (1989/1979) argued that science must move "from epistemology to ontology" (p. 45), a principle that allowed this study to examine sound as both vibration and meaning. Lou (2023) explains that critical realism enables "metatheoretical unity and theoretical pluralism" (p. 142). This was evident in the layered analysis: acoustical physics addressed the material, neuroscience the biological, and ethnography the cultural.

By applying critical realism, the study avoided reductionism. Schlaug (2015) warns that neuroscience risks reductionism if separated from cultural context, while Goldman (2025) critiques ethnomusicology for neglecting the mechanics of sound. Critical realism bridged these divides, showing how material realities (resonance, timbre) intersect with cultural practices (ritual, heritage) and cognitive processes (neural activation). This lens ensured that musical engineering was not reduced to technical analysis but understood as a site of epistemic negotiation.

Curriculum Reform and Policy Implications

The findings also have important implications for curriculum reform. Advocates of STEAM integration argue that music enhances creativity and cognitive skills (Lee, 2025). Turner (NNPA, 2023) insists that "music is not just about notes and lyrics; it goes so much farther beyond that" (p. 6). Our study supports these claims by showing that sound carries cultural meaning and epistemic sovereignty. Curriculum reform should therefore integrate acoustical physics, neuroscience, and decolonial musicology, allowing students to engage with sound as both material and cultural knowledge.

Policy implications extend to funding and educational models. Berklee's interdisciplinary programs show integrative approaches but often lack explicit decolonial frameworks (Berklee Online, 2025). By contrast, incorporating EMPT into policy can ensure that indigenous epistemologies are not marginalized. As Stein and de Andreotti (2017) argue, decolonization in education requires "resisting intertwined processes of colonization and racialization" (p. 370). Supporting musical engineering as an epistemic bridge can guide policies that democratize sonic innovation and promote equity in education.

Limitations

This study acknowledges some limitations. Reliance on secondary neuroscientific data limited the ability to directly measure neural responses across diverse populations. The sample size of 54 participants, while sufficient for qualitative depth, restricts statistical generalizability. In addition, the focus on Nigeria, the USA, and the UK may not capture the full diversity of global sound practices. However, these limitations do not weaken the study's contribution. The emphasis remains on building a nuanced interdisciplinary framework rather than making universal claims, ensuring meaningful progress in advancing musical engineering as an epistemic bridge.

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Implications for Practice

The practical implications of this study extend into the curriculum, policy, and future research. Curriculum reform stands out as a key priority. By presenting musical engineering as a bridge between acoustical physics, neuroscience, and decolonial musicology, educators can reshape the way STEM and the arts are taught, making the model more inclusive. This supports Jørgensen's (2010) point that higher music education has often been "a neglected arena for research" (p. 67), showing the need for approaches that treat sound not only as a scientific phenomenon but also as cultural knowledge. Including musical engineering in curricula would give students the chance to study resonance, timbre, and perception alongside indigenous ways of knowing, helping to democratize learning.

At the policy level, the study calls for more inclusive frameworks in education and research funding. Gilbert and Ubani (2015) argue that the humanities are vital for national development, yet they are often undervalued in policy decisions. Their analysis highlights the importance of weaving cultural knowledge into development strategies, which directly connect to musical engineering. Policies that support interdisciplinary programs and recognize indigenous sound practices as legitimate knowledge systems would ensure that sonic innovation is not limited to Eurocentric traditions but reflects diverse epistemologies.

Finally, the study points toward future research directions. New areas such as AI-driven sound studies and the building of cross-cultural acoustical databases could deepen our understanding of how societies design and interpret sound. These initiatives would expand the scope of musical engineering into global and technological spaces, ensuring that future scholarship remains responsive to both cultural diversity and digital innovation.

CONCLUSION

This study has shown that musical engineering can act as a true bridge, bringing together acoustical physics, cognitive neuroscience, and decolonial musicology. The findings revealed that resonance and timbre are not neutral technical features but are shaped by culture. Neural responses reflect both universal processes and cultural familiarity, while ethnographic evidence highlights sound as a source of justice, used for communication, spirituality, heritage, and technical skill. Together, these insights show that sound is layered and complex, and they affirm the value of critical realism in explaining how material and cultural realities interact.

The main contribution of this research lies in its originality and interdisciplinary reach. By reframing musical engineering as a democratizing knowledge system, the study moves beyond narrow disciplinary boundaries. It answers calls for more integrated approaches in music education and research, echoing Kwami's (1994) view that music education in West Africa must balance indigenous traditions with modern frameworks to stay relevant (p. 534). Nettl (2005) also reminds us that ethnomusicology thrives when it embraces "thirty-one issues and concepts" that cut across cultures and disciplines (p. 12). Building on these insights, this study offers a framework that not only connects science and culture but also places indigenous epistemologies as equal partners in producing knowledge.

In closing, musical engineering is more than a technical or academic exercise. It is a pathway toward epistemic justice and sonic innovation. By democratizing sound studies and embedding

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cultural sovereignty into curriculum reform, Musical Engineering can help reshape education and research for a more inclusive future. As societies continue to face questions of equity and innovation, this framework reminds us that sound, its vibration, perception, and meaning, can be a powerful tool for bridging divides and reimagining knowledge.

Key Takeaways

- **Music as a Bridge:** Musical Engineering connects science, culture, and human experience by linking acoustics, brain science, and decolonial music studies.
- **Sound is cultural:** Resonance and timbre are not just technical features; they carry meaning shaped by traditions, identities, and social contexts.
- **Brains and Beliefs:** Neuroscience shows that music activates universal brain functions, but cultural familiarity makes emotional and mental responses stronger.
- **Justice Through Sound:** Ethnographic studies reveal that music serves as communication, spirituality, heritage, and technical skill, making sound a tool for justice and inclusion.
- **Educational Impact:** Adding musical engineering to curricula can reshape STEM–arts education, ensuring that both indigenous and Western knowledge systems are valued equally.
- **Policy and Research:** Inclusive policies and funding can open sonic innovation to all. Future research should explore AI-driven sound studies and build global acoustical databases.

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