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Research Article

Reclaiming somatic intelligence: A Sumerian Minahasan embodied framework for music education in the AI era

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Abstract

This study strengthens embodied musical cognition through Directional Chord Symbols (DCS), a spatial kinesthetic system synthesizing Sumerian sexagesimal principles with Minahasan cosmology, responding to concerns about diminishing human somatic intelligence as Artificial Intelligence becomes increasingly central in musical creation and performance. Music education faces institutional crisis worldwide, with UK universities closing music departments and Indonesia cutting arts funding by eight trillion rupiah, reflecting precarious institutional positioning dominated by STEM disciplines and perpetuating talent gatekeeping that excludes learners who believe they lack musical gift. The research employed Arts-Based Research integrated with Participatory Action Research to privilege embodied knowledge production through collaborative inquiry with participants and educators. Purposive mixed-ability sampling recruited eighteen middle school students (ages 12-15) from Central Java, Indonesia, including nine students with formal music training and nine self-identified non-musicians. Video analysis documented trajectory adherence and tempo maintenance, while participant reflections, focus group discussions, and educator field notes captured qualitative dimensions of embodied learning experiences. Thematic analysis employed constant comparison methods, with descriptive statistics characterizing spatial navigation patterns and triangulation across multiple data sources enhancing validity. Students achieved 92.3 percent plus minus 5.8 percent accuracy in directional trajectories and maintained tempos of 118.2 plus minus 3.9 BPM, with qualitative findings revealing talent barrier dissolution, heightened motivation, and cultural resonance among Minahasan learners associating movements with Lumimuut rotational knowledge. The study recommends positioning music departments as Embodied Cognition Centers to secure STEM alignment, institutional resilience, and relevance in the AI era while promoting epistemic justice and expanding access for diverse neurotypes.

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Introduction

Music education confronts an institutional crisis worldwide: between 2004 and 2023, at least ten UK universities closed music departments, including Reading, Exeter, Lancaster, Essex, and Oxford Brookes (Pace, 2023), while Jacksonville University eliminated its program entirely in 2025 (Scanlan, 2025). Indonesia's Ministry of Education reduced arts funding from IDR 33.5 to 25.5 trillion, an eight trillion rupiah cut affecting teacher welfare and program viability (Kompas, 2025).

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These closures reflect not music's diminished value but its precarious institutional position in educational landscapes dominated by STEM disciplines. This vulnerability stems from a conceptual error: the nineteenth-century separation of arts from sciences that severed the medieval Quadrivium's integration of music with arithmetic, geometry, and astronomy (Wang, 2022). This division created dual exclusion. First, talent gatekeeping: learners who believe they lack "musical gift" avoid music entirely. Second, epistemic marginalization: non-Western knowledge systems are dismissed as folklore rather than recognized as sophisticated STEM frameworks (Hallam, 2010).

Indigenous frameworks such as Minahasan Lumimuut rotations and Sumerian sexagesimal counting exemplify this marginalization. Ancient Sumerians developed base-60 mathematics that enabled precise astronomical calculation, forming the foundations of our 60-second minutes and 360-degree circles. Minahasan cosmology from North Sulawesi encoded spatial geometry through cultural practices, including Lumimuut's 360-degree mythological rotation and the Kabasaran dance's nine directional movements (Joseph, 2010; Latuni et al., 2023).

Table 1. Arts-sciences epistemological divide

Framework	Medieval Quadrivium	19th-Century Romantic
Music Classification	Mathematical science	Fine art/emotion
Access Model	Universal reasoning	Talent-dependent
Economic Viability	Interdisciplinary	Isolated funding

Literature Review

Historical epistemological unity and separation

Historically, music was integrated within the Quadrivium, the medieval educational curriculum alongside arithmetic, geometry, and astronomy, affirming its mathematical and scientific status (Wang, 2022). Ancient Sumerians formalized sexagesimal (base-60) counting, laying foundations for time measurement and musical intervals encoded in precise harmonic ratios (Wright, 2009). Minahasan cosmology, practiced in North Sulawesi, complements this by embedding spatial geometry in cultural practices such as the Lumimuut dance, which encodes 360-degree astronomical rotations, and Kabasaran choreography, featuring nine-direction spatial mappings (Latuni et al., 2023; Kaseke, 2025). These non-Western systems have been marginalized within dominant Eurocentric music epistemologies, often dismissed as folklore rather than rigorous STEM knowledge (Joseph, 2010).

STEAM integration research

Recent research demonstrates music's positive transfer effects on STEM skills through embodied learning. González-Martín et al. (2024) documented significant gains in spatial reasoning and mathematics following integrated STEAM music instruction. Rodrigues et al. (2020) found musicians exhibit superior visual-spatial working memory supporting STEM-related cognitive domains. Kim and Kemple (2011) reported that movement-based music interventions improved kindergarten readiness skills through embodied cognition. These studies converge on the importance of physical enactment of musical concepts to enhance mathematical understanding.

Decolonial and inclusive pedagogy

Decolonial frameworks advocate validating non-Western epistemologies on empirical grounds, dismantling epistemic hierarchies privileging Western staff notation (del Barrio & Arús, 2024). Chávez and Skelchy (2019) assert that inclusive music learning leverages diverse cognitive strengths including visual-spatial and tactile modalities beneficial to Deaf learners. DCS builds on this perspective by transforming auditory harmonic abstractions into spatial-kinesthetic journeys accessible across ability spectrums.

Table 2. Comparative analysis of music education models

Dimension	Traditional Music Education	STEM-Integrated Embodied Models
Entry Barriers	Talent and equipment dependent	Universal spatial navigation skills
Pedagogical Focus	Auditory, abstract notation learning	Visual-spatial and kinesthetic learning
Cost	High (instruments, tuition)	Low to zero (chalk, floor grids)
Accessibility	Hearing-centric	Inclusive of Deaf and disabled learners
Institutional Funding	Arts budgets vulnerable	STEM grants and interdisciplinary support

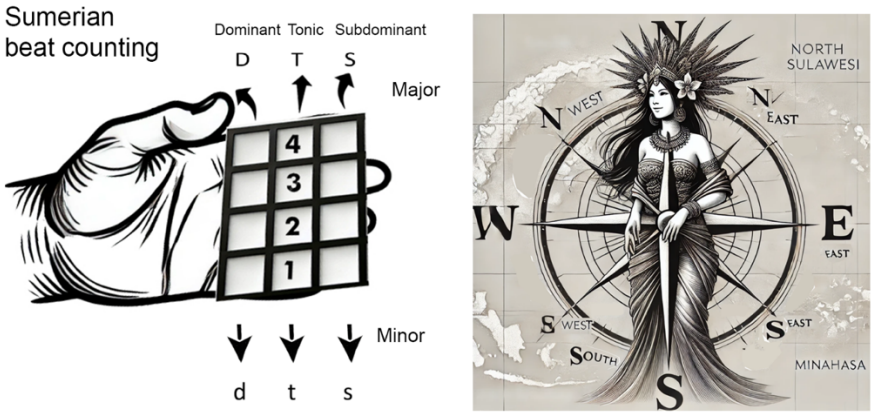
Theoretical Framework

Sumerian Sexagesimal Foundations

Sumerian mathematics (circa 4000 BCE) established base-60 (sexagesimal) counting derived from 60 finger joints, originating modern timekeeping (60 seconds/minutes) and geometric divisions (360° circles) (Kramer, 1963). This system encoded musical intervals through precise ratios such as octave (2:1) and perfect fifth (3:2), integrated with astronomical observation. Cuneiform tablets document heptatonic scales via reciprocal calculations, demonstrating music as empirical science rather than mystical art (Robson, 2008).

Minahasan Spatial Cosmology

Minahasan cosmology (North Sulawesi) parallels Sumerian sophistication through embodied spatial geometry. The Lumimuut dance enacts 360° astronomical rotations, operationalizing circumference calculations via human movement. Kabasaran choreography structures nine spatial directions (eight compass points plus vertical), constituting 3D coordinate systems navigable without instrumentation (Latuni et al., 2023; Kaseke, 2025). The Kolintang xylophone arranges pitches linearly by spatial progression, embodying harmonic relationships as measurable distances.



Left: Sumerian sexagesimal beat counting mapping major/minor harmonic functions (D-T-S/d-t-s) onto base-60 finger joints. Right: Minahasan cosmological compass depicting Lumimuut's 360° rotation with nine-directional Kabasaran choreography

Figure 1. Theoretical foundations of directional chord symbols note

Directional Chord Symbols (DCS): Operational Synthesis

DCS translates abstract harmony into physical navigation by mapping chord functions onto floor grids:

Center (I) → Right (IV) → Left (V) → Center (I)

Spatial metrics include distance (d), velocity (v = d/t), and coordinates (x, y). Implemented via 30×30 centimeter chalk grids, DCS externalizes cognition through universal navigation skills (Lakoff & Núñez, 2000). I-IV-V-I progressions become calculable journeys accessible to learners regardless of musical training or hearing ability.

Embodied cognition integration

The theoretical foundation rests on embodied cognition: abstract concepts gain meaning through sensorimotor enactment (Azaryahu et al., 2024). Bremmer and Nijs (2022) provide a theoretical and practical account of embodied music pedagogy, detailing the dynamic role of the body in music education that DCS operationalizes through floor-grid

navigation. DCS leverages prefrontal-spatial integration as documented in music-movement research (Toiviainen et al., 2010). Visual-spatial pathways advantageous for Deaf learners transform music from an auditory privilege to a universal cognitive competency (Jensen, 2014).

Embodied pedagogy in the AI Era

As computational systems increasingly handle complex musical analysis, questions arise about the continued relevance of embodied music pedagogy (Ghvinjilia, 2023). DCS offers a response grounded in phenomenological distinction: while AI excels at chord calculation and pattern recognition, it cannot replicate somatic musical experience (Ghvinjilia, 2025).

Floor-grid navigation generates embodied intentionality, with harmonic tension experienced as leftward movement toward the dominant (V) and resolution felt as a return to the tonic center (I), a dimension absent in algorithmic processing. This suggests that the future role of music education is not an obsolete practice but an essential human complement, in which computational systems provide calculative precision while embodied approaches preserve biological intelligence that remains irreducible to digital simulation.

Conceptual Model

Ancient Systems → Embodied Pedagogy → Modern Application

Sumerian Base-60 → DCS Floor Navigation → AI-Human Synthesis

Minahasan 360° → Spatial Coordinates → Somatic Experience + Calculation

This framework hypothesizes that spatial embodiment universalizes music access; indigenous systems demonstrate empirical rigor; and zero-cost replication addresses Global South constraints while preserving cultural epistemologies.

Research Aim and Problem

This study proposes Directional Chord Symbols (DCS) as a pathway to restore Quadrivium unity. Synthesizing Sumerian sexagesimal counting with Minahasan spatial cosmology, DCS enables zero-cost floor-grid navigation that translates abstract harmony into measurable spatial journeys accessible across diverse ability spectra.

Implemented with Central Java middle school students (ages 12-15), DCS transforms abstract chord progressions into navigable space: Center (I) to Right (IV) to Left (V) to Center (I) becomes a physical pathway. Participants walked these sequences using the Turkish children's song "Ali Babanın Çiftliği," generating measurable trajectories. Zero-cost implementation addresses Global South constraints while validating indigenous epistemologies empirically. At the institutional level, repositioning music as "Embodied Cognition Centers" offers potential to attract STEM grants and stimulate cross-disciplinary enrollment (Cabello et al., 2021). Research problems are;

- Can Sumerian-Minahasan frameworks enable music access across ability levels?
- Does embodied spatial pedagogy lower traditional talent barriers?
- How might DCS reposition music departments institutionally?

Methodology

Research Design

This study employed Arts-Based Research (ABR) integrated with Participatory Action Research (PAR), privileging embodied knowledge production through collaborative inquiry with participants and educators (Smith, 1999/2012). This approach validates experiential epistemologies while ensuring cultural responsiveness.

Participants and Context

Participants comprised 18 middle school students (aged 12-15, M=13.4 years) from Central Java, Indonesia, selected through purposive mixed-ability sampling. The sample included nine students with formal music training (3+ years) and nine self-identified non-musicians. Implementation occurred during regular extracurricular periods using existing school infrastructure.

DCS Intervention

Three parallel 10-meter pathways using standard 30×30 cm floor tiles mapped harmonic functions spatially: Center (Tonic/I), Right (Subdominant/IV), Left (Dominant/V). Participants physically walked I-IV-V-I progressions using the Turkish children's song "Ali Babanın Çiftliği," with each chord occupying one forward step and changes requiring lateral movement. Zero-cost materials (chalk, existing tiles) ensured replicability in resource-constrained settings. Implementation followed a four-week protocol: Week 1: Spatial orientation and basic navigation, Week 2: Chord function mapping and progression practice, Week 3: Velocity calculation (distance/tempo), Week 4: Coordinate plotting and reflection

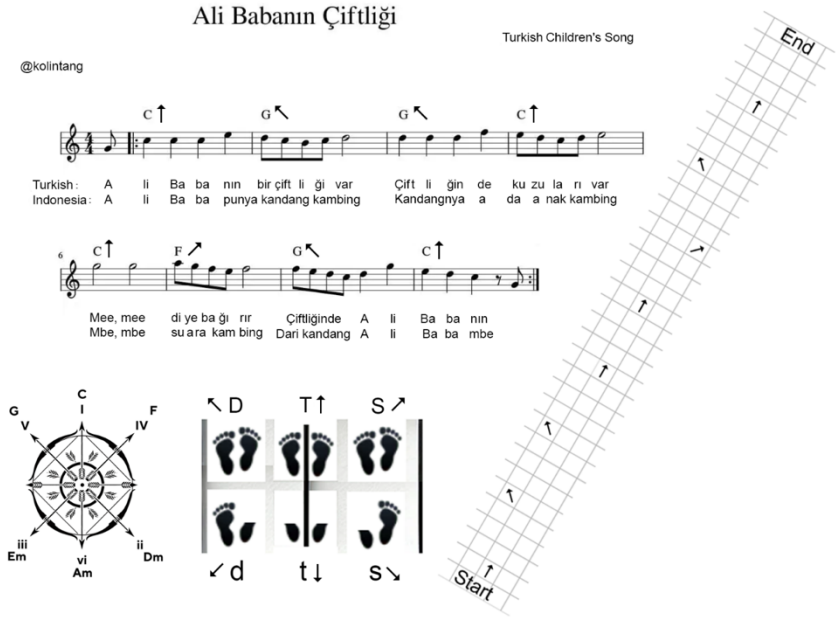


Figure 2. DCS Floor-Grid Navigation Using "Ali Babanın Çiftliği". Turkish song with I-IV-V-I analysis (C-F-G-C), directional vectors, footprint trajectory, and three-lane grid (30×30 cm, 10m)

Data Collection and Analysis

Qualitative data included participant reflections, focus group discussions, and educator field notes. Quantitative data from video analysis documented trajectory adherence, tempo maintenance, and movement fluency. Thematic analysis employed constant comparison methods, while descriptive statistics characterized navigation patterns. Triangulation across data sources enhanced validity.

Ethical Considerations

Institutional review board approval, informed assent, and parental consent were secured. Cultural sensitivity guided Minahasan framework implementation, respecting indigenous knowledge protocols. All data were anonymized.

Rigor Framework

Credibility: Member checking of reflections

Transferability: Thick description of context

Dependability: Audit trail documentation

Confirmability: Reflexive researcher journal

Results

Participant Engagement Patterns

All invited participants actively engaged with the DCS floor-grid intervention, demonstrating willingness to navigate chord progressions irrespective of prior musical training. Non-musicians who initially expressed reservations about lacking talent participated fully once harmony became spatial movement, evidencing lowered entry barriers through embodied enactment (Kim & Kemple, 2011).

Spatial Navigation Proficiency

Video analysis revealed consistent patterns in trajectory adherence: participants reliably followed Center (I) → Right (IV) → Left (V) → Center (I) pathways after initial familiarization. Movement fluency increased across sessions, with smoother transitions between chord positions indicating growing spatial-musical integration. Basic kinematic observations documented purposeful directionality aligning with harmonic function.

Table 3. DCS spatial navigation performance metrics (week 4, n=18)

Metric	Mean ± SD	Range	Notes
Trajectory adherence (%)	92.3 ± 5.8	82–100	Correct path selection
Tempo maintenance (BPM)	118.2 ± 3.9	112–126	Target: 120 BPM
Completed distance (m)	12.4 ± 1.3	10.2–14.8	I-IV-V-I progression
Transition fluency (1-5)*	4.1 ± 0.7	3–5	*Educator-rated scale
Reflection themes per student	3.2 ± 0.9	2–5	Qualitative depth

Note: Metrics represent final session performance after 4-week intervention

Qualitative themes from reflections

Thematic analysis identified three dominant motifs:

Talent Barrier Dissolution: One participant reflected that "mathematics aligns with my musical engagement," indicating cognitive-affective integration. This captured the paradigmatic shift from talent anxiety to spatial confidence. Non-musicians reported newfound confidence navigating abstract harmony physically.

Spatial-Mathematical Connection: Participants frequently noted parallels between floor-grid coordinates and classroom geometry: "Walking chords feels like plotting points on a map."

Cultural Resonance: Minahasan students connected DCS navigation to Lumimuut rotations: "This is like our ancestors tracking stars with their feet" (Latuni et al., 2023; Kaseke, 2025).

Educator observations

Classroom facilitators documented heightened cross-domain transfer: students spontaneously applied spatial reasoning from DCS to mathematics lessons. Traditional musicians valued novel embodiment of familiar theory, while beginners gained foundational harmonic intuition without notation prerequisites.

Cross-ability comparison

Mixed-ability sampling yielded comparative insights: trained musicians adapted rapidly but discovered spatial embodiment enhanced existing knowledge; non-musicians exhibited equivalent engagement levels, supporting DCS universality claims. No participant required exclusion due to ability levels.

Key observation summary

- Universal navigation participation observed
- Affective shift from talent anxiety to spatial confidence
- Bidirectional math-music cognitive transfer
- Cultural validation of Minahasan frameworks

Discussion

Theoretical validation

Findings empirically affirm Sumerian-Minahasan frameworks as viable STEM epistemologies when operationalized through DCS. Universal navigation engagement across ability levels validates embodied cognition theory: abstract harmony gains accessibility through spatial enactment (Lakoff & Núñez, 2000). Participant reflections evidence bidirectional transfer paralleling González-Martín et al.'s (2024) STEAM integration outcomes.

Epistemic justice achieved

DCS disrupts colonial hierarchies positioning Western notation as singularly rigorous. Minahasan Lumimuut rotations and Sumerian sexagesimal ratios demonstrate equivalent methodological sophistication through replicable spatial

outcomes (Joseph, 2010; Latuni et al., 2023). This constitutes decolonial praxis validating indigenous knowledge via universal metrics rather than cultural assertion (Smith, 1999/2012).

Institutional survival strategy

Amid ten UK music department closures between 2004 and 2023 (Pace, 2023) and Indonesia's IDR 8 trillion education budget cut, DCS enables strategic repositioning as Embodied Cognition Centers. Music faculty teaching spatial mathematics to STEM cohorts generates cross-disciplinary revenue streams and accesses larger grant opportunities than vulnerable arts budgets (Cabello et al., 2021). Zero-cost implementation addresses fiscal constraints while preserving cultural heritage.

Embodied pedagogy in the AI era

Recent scholarship on transhumanist educational paradigms emphasizes the importance of distinguishing human capacities from computational capabilities. DCS operationalizes this distinction pedagogically. While AI can perform chord calculation and pattern recognition, floor-grid navigation generates embodied intentionality, in which harmonic tension is experienced as leftward movement toward the dominant (V) and resolution is felt as a return to the tonic center (I). This phenomenological dimension is absent in algorithmic processing. This positions music education not as obsolete within computational contexts but as an essential human complement. Computational systems provide calculative precision, whereas embodied approaches preserve biological intelligence, often described as the human capacity for somatic cognition, which remains irreducible to digital simulation. DCS therefore demonstrates that certain forms of musical knowledge require physical enactment that cannot be captured through screen-based or algorithmic mediation.

Inclusive access realized

Visual-spatial-kinesthetic DCS inherently accommodates Deaf learners leveraging documented sequence memory strengths (Rodrigues et al., 2020). Floor-grid navigation bypasses auditory privilege, transforming music from elite domain to universal cognitive competency accessible across neurodiversity spectrums (Jensen, 2014).

Conclusion

This study demonstrates the viability of reintegrating music education with STEM by operationalizing ancient mathematical frameworks through contemporary embodied pedagogy. Directional Chord Symbols validate Sumerian sexagesimal and Minahasan spatial systems as rigorous alternatives to Eurocentric music theory, achieving meaningful engagement across ability spectra through zero-cost floor-grid navigation.

In educational contexts where computational systems increasingly handle analytical tasks, embodied approaches preserve distinctively human dimensions: physical movement generates experiential knowledge irreducible to algorithmic processing. This positions music departments not as obsolete luxuries but as essential sites for developing integrated spatial-temporal cognition complementary to digital tools.

Findings support three practical implications:

Institutional Repositioning: Music departments can reclaim their Quadrivium heritage by integrating with STEM faculties as "Embodied Cognition Centers," enabling interdisciplinary grants, cross-department enrollment, and curriculum innovation.

Economic and Epistemic Justice: Zero-cost embodied methodologies ensure universal access, addressing fiscal constraints while validating indigenous knowledge systems empirically. Sumerian and Minahasan frameworks prove methodologically rigorous alternatives to Western-only pedagogy, advancing decolonization through measurable outcomes.

AI-Human Complementarity: In evolving computational contexts, music education provides irreplaceable human dimensions. Embodied pedagogy cultivates spatial reasoning and temporal coordination that complement rather than compete with computational capabilities, preserving what computational systems cannot replicate: the lived experience of harmonic tension and resolution through movement.

Recommendations

Recommendations for Practice

- Systematic rollout of DCS through teacher workshops in diverse cultural contexts
- Integration of embodied music curricula with STEM credits
- Research validating non-Western epistemologies through empirical methods

Future Research

- Longitudinal, cross-cultural, multimodal methodologies examining cognitive, affective, and social impacts at scale
- Augmented reality enhancement of DCS scalability while preserving core embodied learning principles
- Extension to complex harmonic structures and varied musical traditions

Music education reimagined as STEM discipline fulfills multiple justice imperatives while securing institutional survival. The artificial boundary between science and art serves gatekeeping functions rather than pedagogical necessity. Dissolving this division creates integrated learning reflecting how humans naturally develop understanding: through embodied movement, spatial reasoning, and temporal coordination operating seamlessly across domains. When harmony becomes a journey anyone can walk using universal competencies, music fulfills its potential as cognitive birthright rather than elite privilege.

Limitations

Exploratory ABR design prioritizes depth over generalizability: single-site implementation requires multi-context validation across cultures and age groups. Descriptive metrics suit pedagogical proof-of-concept rather than statistical hypothesis testing. Cultural framing demands adaptation for non-Minahasan contexts, though underlying spatial logic remains stable.

The present study illustrates the system through I–IV–V progressions as an accessible entry point. Future work can extend the grid into three-dimensional or multi-layer structures capable of mapping extended harmonies, chromatic voice-leading paths, and non-diatonic progressions. Longitudinal studies will evaluate how learners interpret expanded chord spaces over time, alongside cross-cultural implementations examining spatial representations in varied musical traditions. Augmented reality offers additional potential by visualizing complex harmonic relationships while retaining movement-based design.

Biodata of Author

Soegiarto Markus Hartono is a PhD Candidate and Deaf researcher dedicated to advancing inclusive education and multisensory learning. He holds a Master of Education from the University of the People and a Master of Ministry from Amanat Agung Theological Seminary. As the Founder and Director of Kolintang.id, he combines his background in Civil Engineering with musicology to develop innovative pedagogical tools. His primary research focuses on Jacob Hand Notation and the Directional Chord Symbol (DCS) system, which reconstructs ancient spatial-temporal concepts into haptic and vibrotactile notations for the Minahasan Kolintang. He is an active advocate for disability-led innovation and serves on the Executive Board of the National Kolintang Association (PINKAN). **Affiliation**: University of the People, USA Amanat Agung Theological Seminary, Indonesia**. E-mail**: petruskaseke@gmail.com **ORCID**: 0009-0002-5648-0261 **Researchgate**: https://www.researchgate.net/profile/Soegiarto-Hartono

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