

Entry

Sound in STEAM-Based Music Education

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Definition

In science, technology, engineering, arts, and mathematics (STEAM)-based music education, sound serves as a shared object of listening, inquiry, design, representation, and artistic expression. Sound is approached as musical material, a physical phenomenon, a technological object, a design problem, and a mathematical structure. Learners investigate vibration, pitch, loudness, timbre, duration, rhythm, melody, and acoustic experience; use digital tools to record, replay, visualize, arrange, and create sound; and apply design processes to plan, test, revise, and present sound-based products or performances. Musical understanding is developed through singing, movement, instrumental performance, composition, improvisation, and reflection, while mathematical reasoning is supported through beat, duration, sequence, proportion, pattern, and timing. In this approach, music provides an integrated context in which learners connect sensory experience with conceptual understanding. It is relevant across general music education contexts because it supports listening, discrimination, comparison, organization, creation, performance, and reflection, with activities adapted to learners' ages, prior musical experience, and educational levels.

Keywords: sound learning; STEAM education; music education; acoustics; aural skills; music technology; project-based learning; general music education

1. Introduction

Sound is one of the most accessible phenomena through which learners can experience the relationship between science, technology, engineering, arts and mathematics (STEAM) [1–4]. Before students encounter sound as an abstract academic concept, they experience it through everyday listening, speech, song, movement, environmental noise, instruments, rhythm and emotional expression [5–7]. This makes sound a strong foundation for STEAM-based learning across general music education contexts [8,9].

In music education, sound is commonly approached through listening, performance, creative activity, and technology-supported musical interaction [7–9]. These experiences can be supported by formative assessment that documents students' learning processes and musical development [10]. In science education, sound is commonly introduced through vibration, sound sources, wave movement, and sound propagation [11]. In technology-supported learning, sound can be recorded, replayed, visualized, edited, and organized through accessible digital tools [12,13]. Gamified environments can also provide interactive opportunities for practice and feedback [14]. In engineering-oriented learning, sound can be treated as a design object when students plan, construct, test, and revise sound-making objects, digital sound patterns, or musical products through an engineering design process [15]. In mathematics, sound can be organized through beat, duration, sequence, proportion, counting, grouping and pattern [16].



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STEAM-based music education therefore offers more than a simple combination of school subjects [17,18]. It provides an integrated learning environment in which students investigate sound, create with sound, design sound products, perform musical ideas and communicate through sound [18–21]. The arts are not included merely as decoration or motivation [19–21]. Music provides the expressive and structural medium through which scientific observation, technological practice, engineering design and mathematical thinking can become audible and meaningful [21,22].

This entry synthesizes established scholarship on the ways in which sound connects music education with scientific inquiry, digital technology, engineering design, artistic expression, and mathematical reasoning. It reviews the conceptual foundations of sound-based learning, disciplinary connections across STEAM, relevant pedagogical approaches, digital tools and educational games, assessment practices, inclusion and accessibility, illustrative classroom applications, and future directions for research and practice. The synthesis indicates that sound can provide a coherent organizing medium for STEAM-based music learning when disciplinary connections, pedagogical design, assessment, and accessibility are intentionally aligned.

2. Conceptual Foundations of Sound Learning

Sound learning is grounded in the idea that listening is an active, interpretive and creative process [23]. Learners do not simply receive sound. They attend to sound, compare sound, classify sound, interpret sound, organize sound and respond to sound [23,24]. In music education, this process is often associated with ear training, aural skills, rhythmic awareness, pitch discrimination, timbre recognition, melodic memory, ensemble listening and musical interpretation [24–26]. In STEAM education, sound learning expands these processes by connecting musical listening with scientific inquiry, technological practice, engineering design and mathematical reasoning [27,28].

At the most basic level, sound can be understood as vibration and wave propagation [11,29]. When an object vibrates, it produces sound waves that can be perceived by the ear [11]. Students can observe this process through classroom activities, such as striking objects made of different materials, plucking strings, comparing object sizes, feeling vibration through resonant surfaces or using digital tools to view sound waveforms [13,29]. These activities help learners connect sensory experience with scientific explanation [29].

Pitch, loudness, duration and timbre are central concepts in both music and acoustics [30]. Pitch allows students to distinguish high and low sounds [31]. Loudness supports comparison of intensity [30]. Duration connects sound with time [32]. Timbre helps learners identify sound quality, sound source and instrumental color [33]. Rhythm and melody further organize sound into patterned and expressive forms [26,33]. These concepts provide shared vocabulary for both music learning and STEAM learning [30,32].

Sound learning also includes emotional and expressive dimensions. Learners do not perceive sound only in terms of pitch, loudness, duration, or timbre; they also respond to its expressive qualities, musical character, and emotional meaning [7,23]. Within educational contexts, sound learning can therefore be scaffolded from basic auditory noticing and discrimination toward intentional interpretation, coordinated musical action, and creative expression [23,24,26,34,35]. This progression allows sensory responses to become increasingly connected with musical understanding, communication, and purposeful creation.

Sound learning also has an embodied dimension [34,36]. Students often understand rhythm by clapping, stepping, tapping, moving, chanting or performing with instruments [34,36,37]. They understand pitch and melodic contour by singing, listening, matching sound with gestures or connecting heard sounds with visual representations [35]. This embodied experience is important because it makes abstract musical and acoustic concepts

concrete [34,35]. In STEAM-based music education, sound learning is therefore not limited to training the ear, but it becomes a broader process of investigating, designing, creating, performing and reflecting on sound [38,39].

Sound learning may also be understood as an iterative cycle linking repeated listening, auditory representation, embodied action, formative feedback and revision. Repeated listening enables learners to attend to particular sound features and compare successive performances or sound products, while visual representations such as waveforms, symbols and notation make transient auditory information more accessible for analysis [12,13]. Embodied actions, including singing, movement, gesture and instrumental performance, allow learners to test their auditory understanding through physical and musical responses [26,34,35]. Feedback from teachers, peers, recordings and self-evaluation can then help learners recognize differences between intended and produced outcomes [40]. Through repeated cycles of listening, acting, evaluating and revising, students may refine timing, pitch, rhythm, timbre, balance and structural organization. This iterative process connects musical perception with design-based learning because sound products are progressively tested and improved rather than treated as fixed final outcomes [40,41].

3. STEAM Dimensions in Sound Learning

In sound learning, the five STEAM dimensions can be organized around sound as a shared object of inquiry, design, expression, and representation, as summarized in Table 1 [42].

Table 1. Disciplinary perspectives on sound in science, technology, engineering, arts, and mathematics (STEAM)-based music education.

STEAM Dimension	Core Sound-Learning Focus	Typical Classroom Evidence
Science	Vibration, sound source, pitch, loudness, duration and timbre	Students identify sound properties, compare materials and explain sound production
Technology	Recording, replay, waveform visualization, rhythm applications and digital composition tools	Students use digital tools to listen repeatedly, visualize sound and create simple sound sequences
Engineering	Design, testing, revision and improvement of sound products	Students plan, test and revise a sound-making object, soundscape or musical arrangement
Arts	Singing, movement, instrumental playing, composition, improvisation, and performance	Students express ideas musically through voice, body, instruments, digital sound and performance
Mathematics	Beat, duration, pattern, sequence, proportion and timing	Students count beats, divide rhythmic values, organize patterns and coordinate timing

Source: Authors’ synthesis based on the literature cited in the accompanying discussion.

3.1. Science

The science dimension focuses on acoustic phenomena. Students explore how sound is produced by vibration, how materials influence sound quality, how pitch varies with physical properties such as length or tension, how loudness relates to sound intensity, and how timbre helps listeners distinguish sound sources [11,29–33]. These relationships can be examined through observation, prediction, testing, comparison, and explanation [43].

3.2. Technology

The technology dimension includes tools that support listening, recording, visualization, creation, and revision. Digital recorders, mobile devices, waveform displays, and accessible music-creation applications can help students replay, examine, and organize sound [8,12,13]. Technology should function as a tool for inquiry, experimentation, feedback, and creation rather than merely as a delivery device [12,44].

3.3. Engineering

Engineering enters sound learning through design thinking and problem solving. Students may be asked to solve sound-related problems, such as how to create a louder sound, how to design a rhythmic accompaniment, how to construct a simple sound-making object, how to arrange a classroom soundscape or how to improve a group performance. These tasks involve planning, testing, evaluating and revising within an integrated STEM design process [45].

3.4. Arts

The arts dimension is central because sound learning is rooted in musical experience. Students use sound to express emotion, communicate ideas, and perform with others through singing, movement, instrumental performance, improvisation, composition, listening, and reflection [7,8,26,34]. Within STEAM education, art and design contribute disciplinary forms of knowledge and practice rather than serving as decorative additions [28].

3.5. Mathematics

Mathematics appears through rhythm, duration, pattern, sequence, proportion, counting and timing [4,32]. Students count beats, divide durations, recognize repeated patterns, organize phrases and coordinate group performance. Rhythmic notation can also function as a mathematical representation of time [27].

Taken together, these five disciplinary dimensions position sound as a shared object of inquiry, design, expression, and representation within STEAM-based music education, as illustrated in Figure 1.

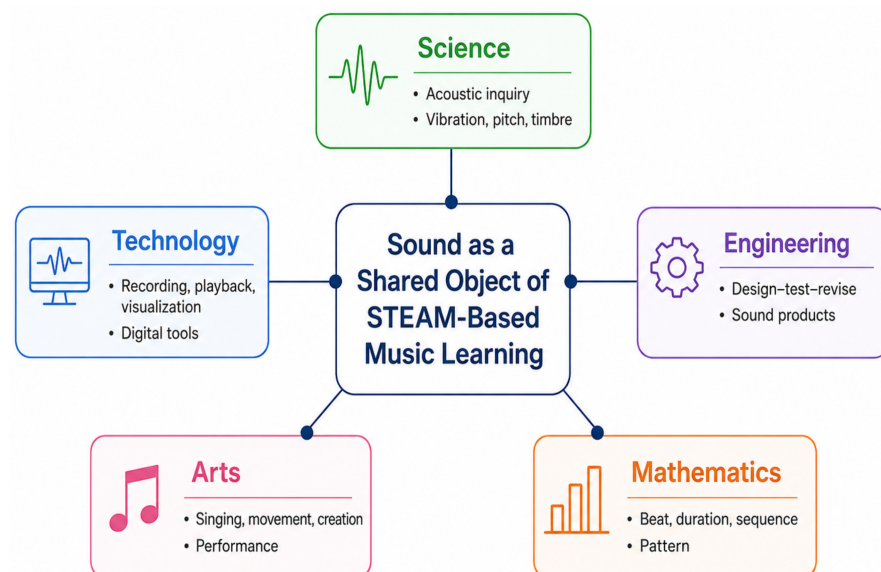


Figure 1. Synthesis of disciplinary connections around sound in STEAM-based music education. Source: Authors' original synthesis.

4. Pedagogical Frameworks

Sound learning in STEAM-based music education can be implemented through several complementary pedagogical approaches rather than a single teaching method [45,46]. In practice, an effective sound-learning lesson may integrate inquiry, project work, design, collaboration, performance and reflection, allowing students to investigate sound scientifically, create musically and evaluate their learning through authentic experiences [41,43,45–47].

Inquiry-based learning begins with questions about sound [29,43]. Students may ask why objects sound different, why some sounds are high or low, why rhythm creates movement or how music communicates emotion. Teachers guide students to observe, test, compare and explain sound phenomena [29,43]. The inquiry process encourages learners to treat sound as something that can be investigated rather than merely heard [29,43].

Project-based learning allows students to create a sound product over time [22,47]. The product may be a rhythm performance, a soundscape, a simple instrument, a digital sound pattern, a short group composition or a classroom performance. The project gives students a meaningful goal and encourages collaboration [45,47]. It also allows different STEAM dimensions to appear naturally within one extended learning task [45].

Design-based learning emphasizes planning, testing and revision [41]. Students do not simply perform a finished task. They improve their work through listening and feedback [40,41]. This approach is especially suitable for sound creation because students can listen to their product; identify problems; and revise timing, balance, timbre, rhythm or structure [12,41].

Collaborative learning is also central. Group sound projects require students to listen to others, coordinate timing, share roles, and negotiate creative decisions [26,47]. Embodied rehearsal and performance further support coordination through movement and musical action [34]. Reflection helps students connect experience with understanding by explaining what they heard, what they changed, why they revised their work and how STEAM dimensions appeared in the activity [40,46].

Together, these approaches also position sound learning as a form of creative and experiential education. Learners are given opportunities to explore sounds and materials, generate multiple musical possibilities, test alternative solutions, and revise their ideas through direct experience [21,22,41,45,47]. Such activities can encourage divergent thinking and discovery-oriented learning because students are not restricted to reproducing a single predetermined musical outcome. Guided experimentation and playful exploration can therefore function as pathways from sensory experience to inquiry, design, musical decision-making, and creative expression.

5. Digital Tools and Educational Games in Sound Learning

Digital tools can strengthen sound learning by making listening more repeatable, visible and interactive [12,13,44]. In conventional classroom listening, sound is transient, which can make detailed comparison difficult. Digital recording allows students to replay sounds and compare specific auditory features [12]. Waveform visualization helps students examine differences in amplitude, duration and temporal pattern [13]. Rhythm applications can support timing practice, while melody-making tools encourage experimentation with pitch, sequence and musical organization [8,12].

Educational games and game-based activities can support learner motivation, engagement and focused practice when their design is aligned with instructional goals [14,48,49]. Rhythm, notation, pitch-discrimination and sound-identification games can provide repeated and interactive opportunities for learners to practice aural and symbolic music skills [9,48,50]. However, the educational value of games depends on their alignment with intended learning outcomes and the quality of the learning experiences they pro-

vide [14,48,49]. Games should therefore function as structured learning tools rather than as entertainment alone, helping learners identify, compare, organize, create and reflect on sound [9,50].

Digital tools are most effective when they are accessible, pedagogically purposeful and closely integrated with classroom tasks [9,12,44]. For younger learners, tools should provide immediate auditory feedback, clear visual representations and opportunities for guided creative experimentation [8,9,40]. Teachers should therefore select technologies according to learning objectives and learner needs rather than allowing the novelty or complexity of the technology to dominate the lesson [12,44].

Digital technology should complement rather than replace learners’ direct engagement with acoustic sound. Interaction with voices, instruments, vibrating objects, body percussion, and environmental sound provides embodied and sensory experiences through which learners can observe, feel, compare, and create sound directly [11,29,34–37]. Digital recording, replay, and visualization can then extend these experiences by making sound available for repeated listening, comparison, analysis, and revision [12,13].

6. Assessment Framework for Sound Learning

Assessment in STEAM-based sound learning should capture both learning outcomes and learning processes [10,51]. Because sound learning includes listening, creating, performing, designing and reflecting, no single assessment method is sufficient [10,51]. A multi-method assessment approach is therefore needed to provide evidence of students’ knowledge, performance, creative processes and reflection [10,40,51].

Drawing on principles of formative, performance-based, and process-oriented assessment [10,40,51], this entry organizes assessment evidence into five complementary areas—listening, performance, sound-product, process, and reflection assessment—as summarized in Table 2.

Table 2. Assessment framework for STEAM-based sound learning.

Assessment Area	Evidence Collected	Educational Purpose
Listening tasks	Sound-source identification, high-low pitch discrimination, timbre comparison, rhythmic recognition and melodic direction	Measures students’ auditory discrimination and conceptual understanding of sound
Performance tasks	Rhythm accuracy, pitch control, ensemble coordination, expressive communication and musical structure	Captures musical understanding through action and performance
Sound-product assessment	Planning, sound selection, pattern organization, testing, revision and presentation	Evaluates design thinking, creativity and technical clarity
Process assessment	Observation notes, worksheets, group work checklists, rehearsal records and reflection sheets	Documents problem-solving, collaboration and revision during learning
Reflection assessment	Student explanation of what was heard, changed, solved and connected across STEAM dimensions	Reveals whether students recognize interdisciplinary meaning in the activity

Source: Authors’ synthesis based on formative assessment principles in music and education [10,40,51].

7. Illustrative Classroom Application in General Music Education

Drawing on established principles of music technology, formative assessment, engineering design, and integrated STEAM education [8,10,15,21,40], Table 3 presents an illus-

trative six-stage sound-learning sequence for general music education. The sequence moves from environmental listening to rhythm and movement, pitch and melody, technology-supported sound creation, rehearsal and revision, and classroom performance and reflection. It is presented as a pedagogical illustration rather than as a report of a new intervention study or as evidence of instructional effectiveness.

Table 3. Illustrative six-stage sound-learning sequence for general music education.

Stage	Learning Focus	STEAM Integration	Typical Evidence
1	Sound and environmental listening	Science through sound-source observation; arts through expressive listening	Sound-source identification, listening worksheet and oral explanation
2	Rhythm and movement	Mathematics through beat and pattern; arts through body percussion and movement	Rhythm performance, movement response and pattern organization
3	Pitch and melody	Science through pitch relationships; arts through melodic singing and listening	High-low discrimination, melodic direction and short melodic creation
4	Musical sound creation	Technology through recording or digital sound tools; engineering through sound-product design	Group sound product, design notes and revision evidence
5	Rehearsal and revision	Engineering through test-revise cycles; arts through ensemble refinement	Peer feedback, rehearsal improvement and performance preparation
6	Performance and reflection	Arts through presentation; mathematics through organized timing; and STEAM integration through reflection	Classroom performance and written or oral reflection

Source: Authors' synthesis based on principles of music technology, formative assessment, engineering design and integrated STEAM education [8,10,15,21,40].

The sequence should be adapted to learners' ages, prior musical experience, available technology, and local classroom conditions. For younger learners, activities may emphasize guided listening, imitation, movement, and exploratory sound-making, whereas older learners may engage in more explicit acoustic analysis, independent design, musical organization, and reflective explanation. Where digital access is limited, teachers may adapt the activities by using body percussion, singing, found objects, and teacher-led listening. Where suitable technology is available, recording and playback can support repeated listening, comparison, and revision [12], while smartphone or tablet-based waveform tools can support the visualization and analysis of sound [13]. Digital tools should be selected with attention to accessibility, learner needs, and inclusive participation [9]. Technological choices should remain subordinate to the intended learning outcomes rather than determining the structure of the lesson.

Implementation also requires alignment between the sound concept, the STEAM connection, the learning activity and the evidence collected for assessment. For example, a lesson on vibration should require learners not only to produce sounds but also to observe and explain how materials or actions influence sound production. A rhythm-design task should include both musical performance and evidence of counting, grouping or pattern organization. A sound-product task should include planning, testing, feedback and revision rather than only the presentation of a finished product [15,21,40].

The six-stage sequence is not intended as a fixed curriculum. Teachers may combine, repeat or extend individual stages according to instructional time and learner needs. Its value lies in demonstrating a progression from perception to investigation, from investigation to creation and from creation to performance and reflection. The sequence also illustrates how music can serve as the organizing medium through which scientific, technological, engineering and mathematical ideas become experientially meaningful.

8. Inclusion and Accessibility

Sound learning can support inclusive education because it offers multiple modes of participation and representation [9,52]. Students can listen, move, draw, speak, sing, play, build, record, arrange or reflect. This flexibility allows learners with different strengths, communication preferences and prior experiences to participate meaningfully.

For students who experience difficulty with conventional notation, sound may be represented through movement, shapes, icons, color, gesture or digital visualization [9,34,35,52]. Students who are less confident in solo performance may participate through group-based sound creation, while students with strong technological interests may use digital tools as pathways into musical understanding. Rhythm, body percussion and movement can similarly support learners who benefit from embodied forms of participation [34,35].

Universal Design for Learning can be applied by providing multiple means of engagement; representation; and action and expression [52]. Teachers may combine auditory examples, visual supports, movement activities, collaborative tasks and alternative ways for learners to demonstrate understanding. Such flexibility should expand access without reducing the musical, conceptual or creative depth of the learning experience.

9. Challenges and Future Directions

Despite its potential, STEAM-based sound learning faces several interrelated challenges. The first concerns pedagogical coherence. Music teachers may have strong artistic and performance expertise but limited confidence in acoustics, engineering design, digital technologies or mathematical representation. Conversely, teachers from STEM backgrounds may use sound primarily to demonstrate scientific concepts without preserving its musical, expressive and cultural dimensions. Professional development should therefore help teachers connect disciplinary knowledge, pedagogical strategies and technological choices rather than simply placing several subject labels within the same activity [1–3,27,44].

A second challenge concerns access, usability and inclusion. Schools differ in their access to mobile devices, recording equipment, software, reliable internet connections and appropriate learning spaces. Digital tools may also create barriers when interfaces are linguistically complex, visually dense or unsuitable for young learners. Sound-learning activities should therefore permit essential learning outcomes to be achieved through both digital and non-digital resources, with multiple means of participation and representation [9,52]. Technology should be selected according to its pedagogical purpose, usability, and relationship to the intended musical task [12,44].

Assessment presents a further challenge because sound learning involves auditory discrimination, performance, creativity, design, collaboration and reflection. These dimensions cannot be represented adequately through a single written test. Teachers need clear criteria for assessing both final products and learning processes, using evidence such as listening tasks, performances, design notes, rehearsal observations, recordings, peer feedback and student reflection [10,40,51].

There is also a risk of superficial integration. A lesson should not be described as STEAM merely because it includes an instrument, a digital application and a counting activ-

ity. Meaningful integration occurs when concepts and practices from different disciplines contribute directly to investigating or solving the same sound-related problem [1–3,21,39]. Future research should examine long-term development in listening, creativity, musical confidence and interdisciplinary understanding; develop valid assessment tools; investigate low-resource implementation; and explore how local music and community soundscapes can be included without reducing cultural practices to decorative examples.

10. Conclusions

Sound learning in STEAM-based music education provides a meaningful interdisciplinary perspective for connecting listening, acoustics, technology, design, musical creativity, and mathematical patterning. It allows students to experience sound as a physical phenomenon, an artistic material, a technological object, a design problem and a mathematical structure. Across general music education settings, this approach can make STEAM learning concrete, active and expressive when activities are adapted to learners' ages, prior experience, and educational contexts.

The strength of sound learning lies in its ability to connect perception with creation. Students hear sound, investigate it, organize it, design with it, perform it and reflect on it. Music education therefore becomes a powerful site for STEAM integration, not because music is added superficially to STEM but because sound itself naturally crosses disciplinary boundaries.

A sound-based interdisciplinary perspective can help teachers design music lessons that are creative, evidence-informed, and accessible. It can also help researchers examine how listening, performance, design and reflection support broader educational goals. As STEAM education continues to develop, sound learning offers a practical and conceptually coherent pathway for connecting musical experience with scientific, technological, engineering and mathematical understanding.

The synthesis and classroom sequence presented in this entry should be understood as an integration of established educational principles and an illustrative pedagogical application. They are not presented as evidence from a new intervention study. Their purpose is to provide a conceptually coherent reference that teachers and researchers may adapt, examine and further develop in different music-education contexts.

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References

- Perignat, E.; Katz-Buonincontro, J. STEAM in Practice and Research: An Integrative Literature Review. *Think. Ski. Creat.* **2019**, *31*, 31–43. [\[CrossRef\]](#)
- Liao, C. From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education. *Art Educ.* **2016**, *69*, 44–49. [\[CrossRef\]](#)
- Quigley, C.F.; Herro, D.; Jamil, F.M. Developing a Conceptual Model of STEAM Teaching Practices. *Sch. Sci. Math.* **2017**, *117*, 1–12. [\[CrossRef\]](#)
- Courey, S.J.; Balogh, E.; Siker, J.R.; Paik, J. Academic Music: Music Instruction to Engage Third-Grade Students in Learning Basic Fraction Concepts. *Educ. Stud. Math.* **2012**, *81*, 251–278. [\[CrossRef\]](#)
- Christiner, M.; Ludke, K.M. Singing-Oriented Language and Music Education (SOLME). *Encyclopedia* **2026**, *6*, 85. [\[CrossRef\]](#)
- Nogueira, C.; Pereira, A.I.; Rodrigues, H. The Senses of Music: Towards a Theoretical Model of Multisensory Musical Experience. *Encyclopedia* **2026**, *6*, 94. [\[CrossRef\]](#)
- Hallam, S. The Power of Music: Its Impact on the Intellectual, Social and Personal Development of Children and Young People. *Int. J. Music Educ.* **2010**, *28*, 269–289. [\[CrossRef\]](#)
- Addessi, A.R.; Anelli, F.; Benghi, D.; Friberg, A. Child–Computer Interaction at the Beginner Stage of Music Learning: Effects of Reflexive Interaction on Children’s Musical Improvisation. *Front. Psychol.* **2017**, *8*, 65. [\[CrossRef\]](#) [\[PubMed\]](#)
- Di Paolo, A.; Todino, M.D. Inclusive Music Education in the Digital Age: The Role of Technology and Edugames in Supporting Students with Special Educational Needs. *Encyclopedia* **2025**, *5*, 102. [\[CrossRef\]](#)
- Kordes, U.; Sicherl Kafol, B.; Holcar Brunauer, A. A Model of Formative Assessment in Music Education. *Athens J. Educ.* **2014**, *1*, 295–308. [\[CrossRef\]](#)
- Hrepic, Z.; Zollman, D.A.; Rebello, N.S. Identifying Students’ Mental Models of Sound Propagation: The Role of Conceptual Blending in Understanding Conceptual Change. *Phys. Rev. Spec. Top.-Phys. Educ. Res.* **2010**, *6*, 020114. [\[CrossRef\]](#)
- Savage, J. Working towards a Theory for Music Technologies in the Classroom: How Pupils Engage with and Organise Sounds with New Technologies. *Br. J. Music Educ.* **2005**, *22*, 167–180. [\[CrossRef\]](#)
- Klein, P.; Hirth, M.; Gröber, S.; Kuhn, J.; Müller, A. Classical Experiments Revisited: Smartphones and Tablet PCs as Experimental Tools in Acoustics and Optics. *Phys. Educ.* **2014**, *49*, 412–418. [\[CrossRef\]](#)
- Christopoulos, A.; Mystakidis, S. Gamification in Education. *Encyclopedia* **2023**, *3*, 1223–1243. [\[CrossRef\]](#)
- English, L.D.; King, D.T. STEM Learning through Engineering Design: Fourth-Grade Students’ Investigations in Aerospace. *Int. J. STEM Educ.* **2015**, *2*, 14. [\[CrossRef\]](#)
- An, S.; Capraro, M.M.; Tillman, D.A. Elementary Teachers Integrate Music Activities into Regular Mathematics Lessons: Effects on Students’ Mathematical Abilities. *J. Learn. Through Arts* **2013**, *9*, 1–19. [\[CrossRef\]](#)
- Radziwill, N.; Benton, M.; Moellers, C. From STEM to STEAM: Reframing What It Means to Learn. *STEAM* **2015**, *2*, 3. [\[CrossRef\]](#)
- Henriksen, D. Creating STEAM with Design Thinking: Beyond STEM and Arts Integration. *STEAM* **2017**, *3*, 11. [\[CrossRef\]](#)
- Liu, C.-Y.; Wu, C.-J. Not Just for Decoration: How the Arts Complement Science, Technology, Engineering, and Mathematics Learning. *Psychol. Aesthet. Creat. Arts* **2025**, *19*, 1248–1258. [\[CrossRef\]](#)
- Segarra, V.A.; Natalizio, B.; Falkenberg, C.V.; Pulford, S.; Holmes, R.M. STEAM: Using the Arts to Train Well-Rounded and Creative Scientists. *J. Microbiol. Biol. Educ.* **2018**, *19*, 19.1.53. [\[CrossRef\]](#) [\[PubMed\]](#)
- Filipe, J.; Baptista, M.; Conceição, T. Integrated STEAM Education for Students’ Creativity Development. *Educ. Sci.* **2024**, *14*, 676. [\[CrossRef\]](#)
- Ramos-Vallecillo, N.; Murillo-Ligorred, V. Prosignification in Art Education: Project-Based and Meaningful Learning Towards Active Learning. *Encyclopedia* **2026**, *6*, 86. [\[CrossRef\]](#)
- Clarke, E.F. *Ways of Listening*; Oxford University Press: Oxford, UK, 2005.
- Karpinski, G.S. *Aural Skills Acquisition*; Oxford University Press: New York, NY, USA, 2000.
- Krumhansl, C.L.; Kessler, E.J. Tracing the Dynamic Changes in Perceived Tonal Organization in a Spatial Representation of Musical Keys. *Psychol. Rev.* **1982**, *89*, 334–368. [\[CrossRef\]](#)
- Zatorre, R.J.; Chen, J.L.; Penhune, V.B. When the Brain Plays Music: Auditory–Motor Interactions in Music Perception and Production. *Nat. Rev. Neurosci.* **2007**, *8*, 547–558. [\[CrossRef\]](#) [\[PubMed\]](#)
- Belbase, S.; Mainali, B.R.; Kasemsukpipat, W.; Tairab, H.; Gochoo, M.; Jarrah, A. At the Dawn of Science, Technology, Engineering, Arts, and Mathematics (STEAM) Education: Prospects, Priorities, Processes, and Problems. *Int. J. Math. Educ. Sci. Technol.* **2022**, *53*, 2919–2955. [\[CrossRef\]](#)
- Bequette, J.W.; Bequette, M.B. A Place for Art and Design Education in the STEM Conversation. *Art Educ.* **2012**, *65*, 40–47. [\[CrossRef\]](#)
- Wittmann, M.; Steinberg, R.N.; Redish, E.F. Understanding and Affecting Student Reasoning about Sound Waves. *Int. J. Sci. Educ.* **2003**, *25*, 991–1013. [\[CrossRef\]](#)
- Fastl, H.; Zwicker, E. *Psychoacoustics*; Springer: Berlin/Heidelberg, Germany, 2007.

31. McDermott, J.H.; Oxenham, A.J. Music Perception, Pitch, and the Auditory System. *Curr. Opin. Neurobiol.* **2008**, *18*, 452–463. [[CrossRef](#)] [[PubMed](#)]
32. London, J. *Hearing in Time*; Oxford University Press: Oxford, UK, 2012.
33. Siedenburg, K.; Saitis, C.; McAdams, S. The Present, Past, and Future of Timbre Research. In *Timbre: Acoustics, Perception, and Cognition*; Siedenburg, K., Saitis, C., McAdams, S., Popper, A.N., Fay, R.R., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 1–19.
34. Juntunen, M.-L.; Hyvönen, L. Embodiment in Musical Knowing: How Body Movement Facilitates Learning within Dalcroze Eurhythmics. *Br. J. Music Educ.* **2004**, *21*, 199–214. [[CrossRef](#)]
35. Bakker, S.; Antle, A.N.; van den Hoven, E. Identifying Embodied Metaphors in Children’s Sound-Action Mappings. In *Proceedings of the 8th International Conference on Interaction Design and Children*; ACM: New York, NY, USA; pp. 140–149.
36. Toiviainen, P.; Luck, G.; Thompson, M.R. Embodied Meter: Hierarchical Eigenmodes in Music-Induced Movement. *Music Percept.* **2010**, *28*, 59–70. [[CrossRef](#)]
37. Burger, B.; Thompson, M.R.; Luck, G.; Saarikallio, S.; Toiviainen, P. Influences of Rhythm- and Timbre-Related Musical Features on Characteristics of Music-Induced Movement. *Front. Psychol.* **2013**, *4*, 183. [[CrossRef](#)] [[PubMed](#)]
38. Chemin, B.; Mouraux, A.; Nozaradan, S. Body Movement Selectively Shapes the Neural Representation of Musical Rhythms. *Psychol. Sci.* **2014**, *25*, 2147–2159. [[CrossRef](#)] [[PubMed](#)]
39. Pepler, K.; Wohlwend, K. Theorizing the Nexus of STEAM Practice. *Arts Educ. Policy Rev.* **2018**, *119*, 88–99. [[CrossRef](#)]
40. Shute, V.J. Focus on Formative Feedback. *Rev. Educ. Res.* **2008**, *78*, 153–189. [[CrossRef](#)]
41. Gómez Puente, S.M.; van Eijck, M.; Jochems, W. A Sampled Literature Review of Design-Based Learning Approaches: A Search for Key Characteristics. *Int. J. Technol. Des. Educ.* **2013**, *23*, 717–732. [[CrossRef](#)]
42. Yakman, G.; Lee, H. Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *J. Korean Assoc. Sci. Educ.* **2012**, *32*, 1072–1086. [[CrossRef](#)]
43. Minner, D.D.; Levy, A.J.; Century, J. Inquiry-based Science Instruction—What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002. *J. Res. Sci. Teach.* **2010**, *47*, 474–496. [[CrossRef](#)]
44. Mishra, P.; Koehler, M.J. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teach. Coll. Rec.* **2006**, *108*, 1017–1054. [[CrossRef](#)]
45. Kelley, T.R.; Knowles, J.G. A Conceptual Framework for Integrated STEM Education. *Int. J. STEM Educ.* **2016**, *3*, 11. [[CrossRef](#)]
46. Hmelo-Silver, C.E. Problem-Based Learning: What and How Do Students Learn? *Educ. Psychol. Rev.* **2004**, *16*, 235–266. [[CrossRef](#)]
47. Bell, S. Project-Based Learning for the 21st Century: Skills for the Future. *Clear. House* **2010**, *83*, 39–43. [[CrossRef](#)]
48. Connolly, T.M.; Boyle, E.A.; MacArthur, E.; Hainey, T.; Boyle, J.M. A Systematic Literature Review of Empirical Evidence on Computer Games and Serious Games. *Comput. Educ.* **2012**, *59*, 661–686. [[CrossRef](#)]
49. Wouters, P.; van Nimwegen, C.; van Oostendorp, H.; van der Spek, E.D. A Meta-Analysis of the Cognitive and Motivational Effects of Serious Games. *J. Educ. Psychol.* **2013**, *105*, 249–265. [[CrossRef](#)]
50. Hands, C. Serious Video Games: Tools for Learning, Training and Health. *Encyclopedia* **2026**, *6*, 83. [[CrossRef](#)]
51. Black, P.; Wiliam, D. Assessment and Classroom Learning. *Assess. Educ.* **1998**, *5*, 7–74. [[CrossRef](#)]
52. Almeqdad, Q.I.; Alodat, A.M.; Alquraan, M.F.; Mohaidat, M.A.; Al-Makhzoomy, A.K. The Effectiveness of Universal Design for Learning: A Systematic Review of the Literature and Meta-Analysis. *Cogent Educ.* **2023**, *10*, 2218191. [[CrossRef](#)]

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