Online Journal of Music Sciences, 2026, 11(1), 30-44
https://doi.org/10.31811/ojomus.1778843

Research Article ♪ Araştırma Makalesi

Investigating common cognitive processes between music and mathematics in educational contexts: a systematic review of the literature

Eğitim bağlamlarında müzik ve matematik arasındaki ortak bilişsel süreçlerin araştırılması: literatürün sistematik bir incelemesi

Karla Valdebenito[1], Sergio Sepulveda-Vallejos[1], Alejandro Almonacid-Fierro[1], Mirko Aguilar-Valdés[1]

[1] Universidad Católica del Maule, Talca, Chile.

ABSTRACT

This article examines the scientific evidence on the intersection of music and mathematics in primary and secondary education, analyzing conceptual foundations such as methodologies and strategies, and demonstrating how their integration improves teaching and student development. A qualitative systematic review, following the PRISMA 2020 guidelines, analyzed 15 studies published between 1998 and 2024 in the Scopus, Web of Science, and EBSCO databases. These studies focused on the cognitive benefits of music education and pedagogical strategies for integrating mathematics learning. The findings present three themes: 1) the cognitive, neurobiological, and educational impact of music education on the mathematics learning process; 2) the relationship between musical skills and logical-mathematical reasoning; and 3) pedagogical proposals and school programs that connect music and mathematics. The results indicate that musical training enhances executive functions, such as working memory, attention, and self-regulation, while facilitating the understanding of abstract concepts through symbolization, rhythm, and pattern recognition. Furthermore, multisensory programs and innovative activities demonstrate that music improves students' motivation and engagement. The evidence supports music as a valuable pedagogical resource that provides inclusive and meaningful learning experiences when integrated into the curriculum.

Keywords: music education, mathematics, cognitive processes, interdisciplinarity, school curriculum

ÖZ

Bu makale, ilköğretim ve ortaöğretimde müzik ve matematiğin kesişimine ilişkin bilimsel kanıtları inceliyor; metodolojiler ve stratejiler gibi kavramsal temelleri analiz ediyor ve bunların entegrasyonunun öğretimi ve öğrenci gelişimini nasıl iyileştirdiğini gösteriyor. PRISMA 2020 yönergelerini izleyen nitel bir sistematik inceleme, Scopus, Web of Science ve EBSCO veritabanlarında 1998 ile 2024 yılları arasında yayınlanan 15 çalışmayı analiz etti. Bu çalışmalar, müzik eğitiminin bilişsel faydalarına ve matematik öğrenimini entegre etmeye yönelik pedagojik stratejilere odaklanmaktadır. Bulgular üç temayı ortaya koymaktadır: 1) müzik eğitiminin matematik öğrenme süreci üzerindeki bilişsel, nörobiyolojik ve eğitimsel etkisi; 2) müzik becerileri ile mantıksal-matematiksel akıl yürütme arasındaki ilişki; ve 3) müzik ve matematiği birbirine bağlayan pedagojik öneriler ve okul programları. Sonuçlar, müzik eğitiminin çalışma belleği, dikkat ve öz düzenleme gibi yürütücü işlevleri geliştirdiğini ve aynı zamanda sembolleştirme, ritim ve örüntü tanıma yoluyla soyut kavramların

Karla Valdebenito — kvaldebenitog@gmail.com
Received/Geliş tarihi: 08.09.2025 — Accepted/Kabul tarihi: 06.01.2026 — Published/Yayın tarihi: 31.01.2026

anlaşılmasını kolaylaştırdığını göstermektedir. Dahası, çok duyusal programlar ve yenilikçi etkinlikler, müziğin öğrencilerin motivasyonunu ve katılımını artırdığını göstermektedir. Elde edilen kanıtlar, müziğin müfredata entegre edildiğinde kapsayıcı ve anlamlı öğrenme deneyimleri sağlayan değerli bir pedagojik kaynak olduğunu desteklemektedir.

Anahtar kelimeler: müzik eğitimi, matematik, bilişsel süreçler, disiplinlerarasılık, okul müfredatı

1. INTRODUCTION

The study of music has been historically linked to mathematics, as shown by Pythagoras' association of musical intervals with numerical proportions (Parncutt & Hair, 2018). In modern education, these relationships are versatile pedagogical tools. Music enhances learning across domains (Manila, 2020), whereas mathematics remains fundamental to school curricula. The integration of these disciplines shares the principles of proportion, symmetry, and sequencing (Hernandez-Olivan & Beltrán, 2023). Music provides a sensory approach that facilitates the understanding of abstract mathematical concepts (Bussu & Mangiarulo, 2024; Shi, 2024). Musical practice through instruments, rhythms, and games provides experiential access to abstract concepts that are typically difficult to grasp using traditional teaching methods (Bussu & Mangiarulo, 2024; Crabtree et al., 2025; Ruth & Müllensiefen, 2021). Music in mathematics promotes an intuitive understanding of concepts such as fractions, enhances retention, and creates a positive learning atmosphere (Alam & Mohanty, 2023; Jian, 2022). However, the mechanisms by which musical instruction influences mathematical cognitive skills remain underexplored, especially in Latin America. Current research varies in terms of context and methodology, creating a fragmented understanding. While systematic reviews have examined the relationship between music education and mathematics performance (Azevedo et al., 2020) and cognitive skills (Maldonado, 2024), this study focuses on pedagogical dimensions and curricular integration in school contexts, considering both students' and teachers' perspectives. Considering this, the research question guiding this review is as follows: What scientific evidence exists on the relationship between music and mathematics in education, particularly in primary and secondary education, considering both its conceptual foundations and pedagogical methodologies and strategies reported in research with students and teachers? Therefore, this study aimed to analyze and synthesize the scientific literature on the link between music and mathematics in both primary and secondary education, considering the empirical evidence on student learning and pedagogical methodologies applied by teachers to integrate both areas in the classroom. This review aims to provide a critical and organized overview of the relationship between music and mathematics in primary and secondary education, identifying the reported effects on student learning and the pedagogical methodologies implemented by teachers to integrate both areas in the classroom.

LITERATURE REVIEW

1.1. Historical and Philosophical Foundations of the Music-Mathematics Relationship

The interrelationship between music and mathematics dates back to the beginnings of Western civilization, when Pythagoras discovered that sounds could be explained through numerical proportions (Cubarsi, 2024). Using a monochord, a string stretched over a resonating box with a movable bridge, Pythagoras demonstrated that changes in the string length altered the pitch. This shows that intervals such as the octave, fifth, and fourth correspond to ratios of 2:1, 3:2, and 4:3, respectively, revealing that consonant sounds correlate with mathematical relationships (Hicks, 2022). This discovery represents an early attempt to conceptualize music through mathematics, showing that music is grounded in universal principles that can be expressed numerically. The Pythagorean scale exemplifies the connection between auditory perception and mathematical organization, influencing Western musical theory (Bergee & Ghorai, 2024). This discovery has two philosophical implications. First, it suggests that the universe follows a mathematical order, with music as its audible manifestation. The Pythagorean "harmony of the spheres" proposes that celestial bodies produce intervals analogous to musical scales (Ciabattoni, 2022). Second, it shows that abstract mathematics and sensory perception are complementary: mathematics explains sensory experiences, whereas music reveals the proportions of nature (Dignam, 2024). The integration of philosophy, science, and art has profoundly influenced the understanding of music and mathematics.

Throughout history, philosophers, musicians, and intellectuals have examined the intersection of music and mathematics. Leibniz (Merikoski et al., 2019) posited that engaging with music is akin to executing mathematical operations. Other theorists, such as Euler and Zarlino, have linked musical compositions to mathematical proportions (Balasubramanian, 2021). Music has been viewed as a domain in which mathematical principles apply to cultural phenomena, bridging abstract reasoning and human sensibilities. While the Pythagorean tradition regarded music as a reflection of the mathematical cosmos, consonance and harmony are now understood as constructs encompassing both the universal principles of auditory perception and cultural conventions. Harmony serves as a bridge between numbers and sounds, constructed from intervals and voice movements that are perceptible through musical instruments (Di Stefano & Spence, 2022). Mathematics in music has evolved into a dynamic language engaging cultural, biological, and aesthetic dimensions, with Pythagorean proportions serving as the foundation for new musical interpretations. Drawing on these historical and philosophical foundations, one can understand how numbers and sounds relate to the organization of the world and human experience. Mathematical principles in music, from Pythagorean proportions to research on timbre and perception, have influenced musical theory and science philosophy, offering opportunities to connect these mutually illuminating disciplines.

1.2. Cognitive processes shared between music and mathematics

Recent investigations in cognitive psychology and neuroscience have revealed that music and mathematics share a common cognitive framework through the processes of perception, memory, attention, and reasoning (Harney, 2020). Although traditionally viewed as distinct disciplines, significant similarities exist in the underlying mental and neural processes. These similarities explain the correlation between musical training and enhanced mathematical performance (Bergee & Weingarten, 2021). Rhythm, melody, and harmony constitute organized structures that performers must identify and engage with (Ramos, 2022), whereas mathematics relies on numerical, geometric, and logical patterns to solve problems (Gripton, 2023). In both cases, cognitive processes detect regularities and abstract generalizations, highlighting the connection between musical training and mathematical skill. The development of abstract thinking is crucial in both disciplines, involving concepts that lack concrete representations. In music, this manifests through scales, chords, and harmonies (Szűcs & Juhász 2023), whereas mathematical ideas exist as mental constructs (Hanif et al., 2021). Both disciplines require logical thinking and problem-solving. Music involves recognizing rhythms, dynamics, and harmonies (Kang, 2024), whereas mathematics involves identifying elements, discerning connections, and devising solutions (Lovianova et al., 2022). Music study enhances planning and self-regulation skills linked to MR., and the literature shows that music and mathematics share cognitive foundations in pattern recognition, symbol manipulation, and sustained attention (Khatin-Zadeh & Hu, 2024; Zhao, 2024). Musical language uses symbols to generate sounds, similar to the use of symbols and rules in mathematics. Musical learning improves the understanding of temporal and spatial concepts, connecting them to numerical reasoning and problem solving (Nisha et al., 2022). Students who study music develop enhanced abilities to comprehend and organize information, thereby improving their logical-reasoning skills. In conclusion, music and mathematics share commonalities in cognitive skills, symbol recognition, abstract thinking, memory, and planning skills. These shared skills explain why musical education facilitates learning in mathematics. Beyond this practical contribution, they also serve as reminders that art and science are not disparate realms but rather distinct expressions of the same human capacity: the ability to organize, understand and interpret the workings of the human mind.

1.3. Asymmetry in the Educational Assessment of Music and Mathematics

The evaluation of music and mathematics in school education reveals persistent inequalities in curriculum policy and resource distribution. Mathematics is positioned as a core discipline, assessed through standardized systems, and associated with essential literacy for citizenship and employability. In contrast, music is often relegated to the periphery of education, perceived as entertaining but replaceable, and frequently excluded from national assessment systems (Akın, 2025). Scholars such as Bryan Caplan from George Mason University advocate that schools should focus on reading and mathematics, viewing them as the only skills with clear economic returns in adult life (Zimmer, 2022). This perspective considers music and arts to have limited practical utility, with their role in formal education deemed marginal, as they do not directly enhance labor productivity. This discourse legitimizes policies prioritizing mathematics while relegating music to an auxiliary role (Ferrada, 2020). This disparity is both symbolic and economic: mathematics is portrayed as the gateway to prestigious professions, while music remains associated with the "starving artist" myth, despite the significant contributions of cultural industries (Alam & Mohanty, 2023). This creates an imbalance in resource allocation and public discourse, suggesting that mathematics "pays

off" while music is supplementary. Within educational systems that use standardized tests, core subjects, especially mathematics, receive increased instructional time, monitoring, and resources (Trgalová & Tabach, 2023). Meanwhile, the arts have undergone cycles of reconfiguration, reduced hours, and resource scarcity (Hassan, 2023). Schools disseminate knowledge and legitimize social interaction (Spiro, 2025). Music fosters belonging, care, and symbolic agency; its marginal presence reduces education to quantifiable outcomes (Alam & Mohanty, 2023). Conversely, acknowledging music's ability to enhance and improve mathematical outcomes also suggests that comprehensive human development requires spaces for listening, composition, and performance, where identity and meaning are interwoven. In this context, the connection with mathematics can be twofold: instrumental, involving cognitive transfers that support numerical, geometric, or statistical learning, and intrinsic, offering an alternative approach to cultivating attention, structure, and beauty, which are also inherent in mathematics (Lingefjard & Hatami, 2020).

How should schools address the imbalance between mathematics and music in their curricula? Several methods have been suggested to address this issue (López et al., 2021; Trienekens et al., 2024; Yang et al., 2024). First, we should not view mathematics and music as separate entities. Instead, we should combine them when it makes sense to do so in the future. Second, we should not rely solely on standardized tests to judge their importance. Just because something is difficult to measure does not mean that it is not valuable. Third, we need to match what we say about STEAM (Science, Technology, Engineering, Arts, and Math) with what we do in practice. Projects should show that mathematics is more than just numbers and that music is more than decoration. Both subjects should help us understand and create knowledge about the world. Fourth, teachers require better training to combine these subjects effectively. Without training and resources, good ideas remain as ideas. Finally, we should value music for its own sake, not just for how it helps other subjects to learn. Music helps us understand, feel, and find meaning, which is important for education and learning. The imbalance between music and mathematics is not just about status. This is an opportunity to teach better methods. In a system that teaches students to think, create, and live together, it makes no sense to ignore subjects that help develop these skills. By allowing mathematics and music to work together, we can balance the curriculum and help students learn more deeply and effectively. The goal is not to lower the value of mathematics but to raise the value of music education. Together, they show the connection between numbers and sounds. Third, aligning STEAM rhetoric with practices is vital: interdisciplinary projects should ensure that mathematics is not reduced to computation or music to embellishment, but that both contribute their grammar to modeling phenomena and designing artifacts. Fourth, enhancing teacher training for integration is essential through professional development, planning, and resource allocation. Finally, music's value in education extends beyond "enhancing" other areas to fostering experiences of understanding and meaning that democratic education requires. The asymmetry in the educational valuation of music and mathematics presents pedagogical opportunities. In preparing students to think critically and create freely, marginalizing a discipline that cultivates the cognitive processes required by "core" subjects is illogical. Engaging both disciplines without subordination allows curriculum rebalancing and honors the complexity of learning. The evidence advocates elevating music's status so that, together with mathematics, it illuminates the unity between form, structure, and experience, which is inherent in both numbers and sounds.

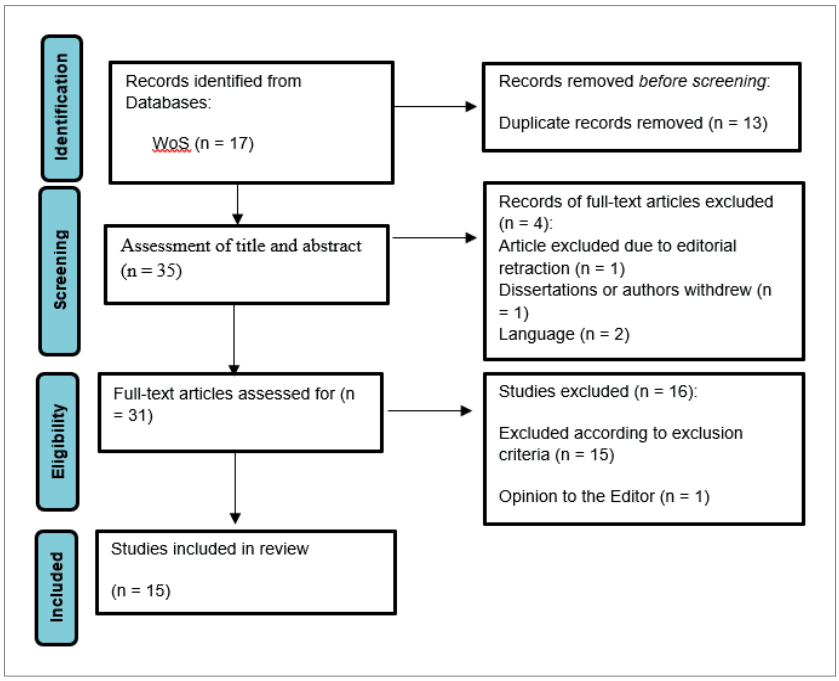
2. METHODOLOGY

This qualitative systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021) to ensure transparency and methodological rigor of the review process. This study examined the relationship between music and mathematics in primary and secondary education by analyzing the influence of music education on mathematics learning and subject integration in classrooms. The objective of this study was to provide a comprehensive overview of pedagogical practice and future research.

The study selection process comprised four phases and is summarized in the PRISMA flow diagram (Figure 1).

Figure 1

PRISMA flowchart of the study selection process



2.1. Identification

During the identification phase, a comprehensive search was performed across international academic databases, including Scopus, Web of Science, and EBSCO. The search employed the following keyword combinations: "mathematical" AND "skills" AND "musical" AND "training." Owing to the limited scientific literature available on this subject, no specific temporal restrictions were applied, allowing for the inclusion of as many pertinent studies as possible published in both English and Spanish. The initial search strategy yielded 48 articles from the databases: WoS: 17 articles, Scopus: 16 articles, and EBSCO: 15 articles. Subsequently, 13 duplicate articles were eliminated, resulting in 35 unique studies being included in the screening phase.

The search strategy employed a set of specific keyword combinations derived from a review of articles relevant to the study focus. This approach ensured the use of appropriate academic language and specificity in identifying studies that directly addressed the integration of music and mathematics in educational contexts. Following several trial searches to pinpoint the research objective, the keywords were refined to align with the specific disciplines identified, such as arithmetic, interdisciplinary learning and cognitive transfer. This aspect represents a limitation of this review and was considered when interpreting the findings.

2.2. Screening

In the second stage, the 35 non-duplicate studies underwent a review of their titles and abstracts to determine their relevance to the integration of music and mathematics in primary and secondary school students in school settings. Therefore, predefined inclusion and exclusion criteria were applied in this phase to ensure the suitability and quality of the evidence collected (Table 1). This process facilitated the elimination of articles that did not meet the requirements for document type, language, educational level, or subject area, such as university or non-educational contexts, such as music conservatories. This process allowed us to narrow down a subset of 19 articles that were potentially eligible for further analysis.

Table 1

Inclusion and Exclusion Criteria

Type of Criteria	Inclusion Criteria	Exclusion Criteria
Topic/ Thematic focus	Studies that exclusively cover mathematics and music in a primary and secondary educational context.	Studies addressing music and mathematics as independent subjects, without explicit pedagogical or cognitive integration.
Language	Studies published in English, Spanish, and Portuguese.	Studies published in languages other than English, Spanish, or Portuguese.
Publication Type	Articles in peer-reviewed scientific journals.	Theses, conference proceedings, book chapters, editorials, or non–peer-reviewed sources.
Topic Disclosure	Studies that integrate music as a pedagogical tool in mathematics teaching.	Studies that address music and mathematics education separately, without integration.
Educational Level	Studies located in primary and secondary school settings, directly involving teachers and/or school environments.	Studies conducted exclusively in higher education, informal learning, or non-school contexts.

Subsequently, after an intensive reading of the articles, the criteria established in Table 1 were applied again, resulting in the exclusion of four articles for the following reasons: editorial retraction, withdrawal of the manuscript by the authors, and use of languages not considered in this review (i.e., Russian). Finally, 15 studies met the inclusion criteria and were incorporated into the final qualitative analysis.

2.3. Eligibility

During the eligibility phase, 15 articles were confirmed based on their direct relevance to the relationship between music and mathematics in primary or secondary education, from either a pedagogical or systemic perspective. This ensured the thematic and methodological coherence of the analyzed corpus. Data extraction was performed independently by two researchers using a standardized template that recorded the authors, year of publication, country or region, research design, objectives and main findings. Any discrepancies were resolved through discussion and, if necessary, by the participation of a third reviewer. The selected studies were subsequently subjected to thematic analysis, following the six-phase model proposed by Braun and Clarke (2019): 1. Data familiarization, 2. Initial code generation, 3. Theme search, 4. Theme review, 5. Theme definition and nomenclature, 6. Report preparation.

Beyond the selection process, the methodological quality of the included studies was assessed by reviewing each study's design, sample size, clarity of methodology, and potential biases. Given the variety in designs and outcomes, formal bias risk scales will not be used; instead, quality considerations will be integrated into the interpretation of the results.

3. FINDINGS

The studies examined in this literature review demonstrated significant variations in their research design, sample size, and methodological rigor. While most studies employed qualitative or mixed-methods approaches, a smaller number employed experimental or quasi-experimental designs. The sample sizes varied from small to context-specific, limiting the generalizability of the findings. Additionally, several studies relied on correlational analyses or short-term interventions without a control group, increasing selection bias and limiting causal inferences. These methodological characteristics were considered when interpreting the results presented below. To provide a clearer view of the characteristics of the selected studies, the Figure 2 illustrate their geographic distribution and evolution.

Figure 2

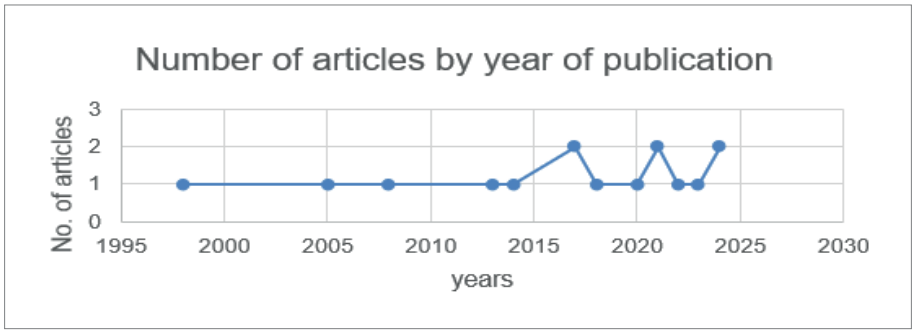
Map of scientific production on mathematics and music

The global map illustrates the geographical distribution of the research sites. Collectively, the 15 studies encompassed 10 countries, with the United States (four studies), Brazil (three studies), Portugal (two studies), and Spain (two studies) being the most prominent. Additionally, Russia, China, England, Italy, Ireland, and Argentina were represented by single studies. Notably, some studies were conducted across multiple countries, resulting in the total number of mentions per country exceeding the number of individual articles.

The articles covered the period from 1998 to 2024, with temporal research in the early years (1998, 2005, 2008, 2013, and 2014) and a sustained increase in the last decade. The growing academic interest in the integration of music and mathematics is reflected in the increase in productivity in 2017, 2021, and 2024 (Figure 3).

Figure 3

Temporal evolution



In terms of methodology, most studies utilized qualitative and mixed-method approaches, employing interviews, case studies, and questionnaires as primary data-collection techniques. A smaller subset of studies adopted experimental or quasi-experimental designs. This methodological diversity facilitated an exploration of the relationship between music and mathematics from an educational perspective, incorporating teaching experience and student engagement. To provide a more systematic overview, Table 2 provides a methodological summary and the principal findings of the 15 studies selected for the review.

Table 2

Methodological synthesis and key findings of the studies analyzed

1	Azevedo et al. (2020)	Systematic review of studies	This study examined musical training's impact on academic performance, mathematics, cognitive functions and brain plasticity.	Research on the impact of musical training on academic performance has shown mixed results, although cognitive benefits and brain plasticity changes have been documented.
2	Cheek & Smith (1999)	Correlational quantitative	This study examined the relationship between musical ability and mathematical learning in 53 elementary students by correlating musical aptitude scores with math test results.	Musical abilities, especially rhythm skills, positively correlatedively with mathematical performance, suggesting that musical training may enhance mathematical reasoning.
3	Da Silva et al. (2017)	Prospective, blinded, pseudorandomized study testing a numerical music training (NMT) program	This study assessed NMT's effects of NMT on abstract reasoning, working memory, and numeracy at two time points.	Neurocognitive Music Therapy (NMT) may enhance early cognitive abilities, including numerical cognition and working memory, but this requires empirical validation.
4	Forgeard et al. (2008)	Correlational study comparing children with at least three years of instrumental music training	This study examined how music training affects auditory discrimination, motor skills, vocabulary, and nonverbal reasoning.	Instrumental music training correlates with enhanced cognitive abilities, though not universally across domains.
5	Foster (2013)	Theoretical and pedagogical analysis proposing a music-inspired approach to mathematics instruction.	This study examines how high-stakes assessment affects mathematics learning and proposes harmonizing procedural fluency with creative problem solving.	This study proposes integrating technical practice with research to enhance mathematics teaching through traditional and progressive strategies in coordinates, equations, and extensions.
6	García-García et al. (2024)	Observational/ comparative study with pre post tests	Statistical analyses compared mathematical creativity and performance in students with and without musical training, controlling for prior performance, socioeconomic status, and cultural background.	Musical training correlates with enhanced mathematical creativity and academic performance, suggesting links between these domains.
7	Incógnito et al., (2022	Experimental study with a pretest-posttest design	This study evaluated how a music education program affects meta-musical awareness and cognitive abilities, including logical-mathematical and notational skills.	Musical training enhances meta-musical awareness and notation skills without significantly affecting logical-mathematical abilities.
8	Kazantseva et al. (2023)	Genetic association study using real-time PCR to genotype nine gene variants in 100 musically skilled students and a 200-person control group.	Genetic factors affecting musical abilities were examined by analyzing gene variants linked to music perception and performance.	Genetic variants of SNCA, GATA2, and ASAP1 predict enhanced musical aptitude, implicating dopaminergic mechanisms in musical skill acquisition.
9	Maldonado (2024)	Systematic review	Examine musical education's effects on preschoolers in Latin America and Argentina, analyzing cognitive and social impacts.	Music education impacts Latin American preschoolers' cognitive abilities and social development in Argentina, enhancing memory, attention, empathy, and cultural identity, despite resource limitations.

Table 2

Continued

Nº	Article	Research method	Study description	Findings
10	Piñero et al. (2021)	Quasi-experimental with pretest-posttest design and control group.	Five kindergartens in Azerbaijan with 90 children aged 5-6 participated. The experimental group engaged in music-integrated activities, whereas the control group received traditional instructions.	Five kindergartens in Azerbaijan (90 children aged 5-6) participated, with the experimental group receiving music-integrated activities and the control group receiving traditional instruction.
11	Ribeiro & Santos (2017)	Systematic review	This study examines how music education affects intellectual skills such as mathematics and reading among primary school children.	This study advocates standardizing music research methods and subdividing intellectual abilities to analyze cognitive transfer from music education.
12	Ribeiro & Santos (2020)	Longitudinal quasi-experimental study with a double-blind design.	This study examined the effects of musical training on numerical cognition and visual reasoning in primary-school children.	Music therapy enhances numerical skills in children with developmental challenges, but not visual reasoning abilities.
13	Schlaug et al. (2005)	Longitudinal and cross-sectional studies.	This study examined brain differences associated with music training, focusing on training intensity, duration, and contributing factors.	Musical training enhances children's cognitive abilities, and further research is needed to understand its effects.
14	Szirony et al. (2008)	Correlational quantitative; HIPS (Human Information Processing Survey) scale	This study examined the correlation between hemispheric dominance and music-math competencies by using the HIPS questionnaire.	Musical aptitude was correlated with right-hemisphere processing, while mathematical aptitude showed marginal links.
15	Yang et al. (2014)	Comparative study	This study examined how prolonged music training influences academic development in L1, L2, and mathematics.	Musical training can enhance certain cognitive and academic skills; however, its effects vary. Therefore, a cautious interdisciplinary educational approach is advised.

To systematically organize the findings of the 15 selected articles, thematic categorization was conducted, enabling the grouping of studies based on their primary contributions. This classification facilitated a comparative analysis and identification of common patterns in the reviewed literature. These categories represent the key areas where empirical evidence has been concentrated: 1) the cognitive, neurobiological, and educational impact of music education on the process of learning mathematics; 2) the relationship between musical skills and logical-mathematical reasoning; and 3) pedagogical proposals and school programs that connect music and mathematics. Table 3 presents the distribution of articles within each category along with their respective authors.

Table 3

Categories created from the analysis of selected articles

Category	Authors
1. Cognitive, neurobiological, and academic impacts of music education on mathematics learning	Azevedo et al. (2020); Forgeard et al. (2008); Incógnito et al. (2022); Kazantseva et al. (2023); Maldonado (2024); Ribeiro & Santos (2017); Schlaug et al. (2005); Szirony et al. (2008); Yang et al. (2014).
2. Links between musical skills and logical-mathematical reasoning	Cheek & Smith (1999); Da Silva et al. (2017); Foster (2013); García-García et al. (2024).
3. Pedagogical proposals and school programs that articulate music and mathematics	Piñero et al. (2021); Ribeiro & Santos (2020).

3.1. Cognitive, neurobiological, and academic impacts of music education on mathematics learning

Recent scientific literature has demonstrated that music education yields benefits beyond the artistic domain, including attention, memory, language, executive functions, and language-related skills (Azevedo et al., 2020; Maldonado 2024). However, evidence regarding its direct impact on mathematical performance is inconsistent. While some studies report improvements in academic outcomes, others suggest that gains are domain-specific or indirect, highlighting variability according to the intervention design and cognitive focus (Incógnito et al., 2022). According to Schlaug et al. (2005), musical training augments brain regions associated with auditory and motor functions. Kazantseva et al. (2023) argued that musical talent involves cognitive skills related to spatial and mathematical processing. Maldonado (2024) concluded that singing and playing instruments enhance memory, attention, and mathematical skills, while providing emotional and social benefits. A study in Argentina interpreted the results from a Latin American perspective, emphasizing inclusive music education while noting constraints of inadequate teacher training.

Research within the reviewed literature suggests that musical training is associated with alterations in brain regions involved in auditory-motor processing and cognitive skills, which are linked to spatial and mathematical reasoning (Schlaug et al., 2005). These cognitive effects are accompanied by emotional and social benefits, particularly when musical activities involve singing or playing instruments (Kazantseva et al., 2023). In the Latin American context, Maldonado's study (2024) presents music education as an inclusive activity; however, challenges related to infrastructure and teacher training persist.

3.2. Links between musical skills and logical-mathematical reasoning

The interrelationship between musical and mathematical skills has been extensively examined from empirical, theoretical, and pedagogical perspectives. Various studies have demonstrated that music, through rhythm, structure, and temporal perception, activates cognitive processes such as working memory, attention, and pattern recognition, which are fundamental to mathematical reasoning (Cheek & Smith, 1999; García-García 2024). Evidence suggests that musical interventions can foster the development of cognitive skills linked to numerical cognition, creativity, and visuospatial memory, especially when implemented in early childhood and formal education (Da Silva et al., 2017). This suggests that music facilitates concept understanding and promotes divergent thinking. However, studies caution that this relationship should not imply an automatic advantage for those with musical training over those with mathematical training.

Research consistently indicates a correlation between extended musical training and enhanced mathematical reasoning abilities, particularly through cognitive processes such as attention, memory, and pattern recognition (Cheek & Smith, 1999). From a pedagogical standpoint, Foster (2013) drew a parallel between the study of mathematics and music, observing that both fields necessitate systematic technical skills in conjunction with student expressions and reflections. This comparison implies that the principles of music pedagogy can inspire innovative mathematical tasks. The interplay between musical and logical-mathematical skills illustrates that musical activities augment the cognitive functions associated with acquiring mathematical knowledge. The literature consistently demonstrates that music facilitates the development of mathematical competence, highlighting the importance of integrating both disciplines in educational settings to promote holistic learning.

3.3. Pedagogical proposals and school programs that articulate music and mathematics

The integration of music and mathematics in educational contexts has prompted proposals aimed at enhancing mathematical comprehension through musical resources. The studies examined in this domain reveal interdisciplinary approaches grounded in active methodologies, which facilitate the activation of curricular knowledge, bolster motivation, and foster student engagement in the learning process (Piñero et al., 2021; Ribeiro & Santos, 2020). This study demonstrates that integrating musical activities with mathematics fosters meaningful learning, highlighting the importance of interdisciplinary approaches in primary education.

4. DISCUSSION

The findings of this systematic review underscore the influence of music on the educational environment across learning dimensions, with mixed results. Regarding the cognitive, neurobiological, and academic impacts of musical training, studies have highlighted its benefits of musical training on memory, attention, and

self-regulation, as well as neurobiological changes associated with brain plasticity and executive functioning (Forgeard et al., 2008; Maldonado, 2024; Ribeiro & Santos, 2017, 2020). However, studies have shown limited effects on mathematical performance (Azevedo et al., 2020), indicating that the benefits depend on contextual factors and learner characteristics. The literature emphasizes the need for longitudinal research with experimental controls to clarify the associations between these variables. It is crucial to recognize that the strength of the identified associations varies with the study design, duration of the intervention, and outcome measures. Correlational and short-term studies often report moderate or inconsistent effects. This methodological variability limits the ability to draw causal inferences from current evidence.

Recent studies have reinforced the connection between music education and mathematics learning. Musical practice enhances working memory, attention, executive function, planning, and cognitive flexibility, which are crucial for logical-mathematical reasoning. It improves abstract reasoning and spatial perception, which are integral to solving mathematical problems. Neurobiologically, changes include increased gray matter, a thicker corpus callosum, and an enlarged hippocampus, which facilitate interhemispheric communication. However, these neurobiological discoveries do not always align with observable enhancements in mathematical abilities and should, therefore, be considered as possible mechanisms rather than direct results. The findings indicate that musical training enhances overall performance, particularly in mathematical reasoning, as musical concepts are related to numerical structures. Rather than having a direct effect, evidence suggests that music education might support mathematical learning indirectly by improving essential cognitive functions. Evidence supports that music education develops skills that influence complex learning, although debate continues regarding the magnitude of these improvements across different contexts.

The second category examines the relationship between musical, logical, and mathematical skills as a structural connection among these disciplines. Studies (Cheek & Smith, 1999; Da Silva et al., 2017; Foster, 2013; García-García et al., 2024) show that this connection is based on shared principles such as rhythmic organization, proportion, and pattern recognition, facilitating pedagogical links between musical and mathematical content. Research shows that this connection extends beyond cognitive impacts, highlighting structural similarities that are beneficial for teaching. Nevertheless, the extent to which these common structures result in measurable learning outcomes varies across studies, primarily because of differences in research design and the types of educational interventions employed in each study. Some studies emphasize cognitive transfer, while others interpret the connection more as a pedagogical or representational analogy rather than a direct impact on learning. Global evidence demonstrates that music enhances logical-mathematical thinking by incorporating abstract ideas into creative processes. While this improvement should be approached with caution, it acts more as a facilitator or mediator in the learning process rather than a direct outcome of musical training.

In the third category, educational proposals that integrate music and mathematics have emerged as effective pedagogical methods. These initiatives use music to address mathematical concepts and create meaningful learning experiences. Piñero et al. (2021) and Ribeiro and Santos (2020) show that this integration enhances student engagement and aids comprehension of concepts like fractions and patterns. Da Silva et al. (2017) demonstrated that "doing mathematics with music" transforms music into a mathematical object using digital tools to identify mathematical concepts, promoting active learning without requiring musical training. The effectiveness of these methods largely hinges on the specific instructional design, the level of teacher involvement, and the particular context in which they are implemented, which limits the ability to generalize the findings across various educational settings and contexts. These experiences show that music-mathematics integration broadens pedagogical possibilities while addressing comprehensive student development needs.

In summary, the reviewed studies indicate that the interplay between music and mathematics manifests in various dimensions: cognitive, structural, and pedagogical. While the findings affirm the presence of benefits and shared elements, they also reveal diverse outcomes contingent on factors such as age, educational context, and the methodological design. It is important to recognize that the variability in the evidence cautions against making sweeping claims about effectiveness and highlights the need to view reported benefits as context-dependent rather than inherent to integration. In this context, current evidence does not support direct causal claims regarding the effect of musical education on mathematical performance in children. Rather, it suggests that the relationship is indirect or mediated and is shaped by cognitive and teaching processes. These complexities suggest that the integration of these disciplines represents a promising yet evolving area of study, necessitating further empirical investigation to ascertain its full potential.

5. CONCLUSSION

This systematic review elucidates the complex interplay between music and mathematics in educational contexts, emphasizing their influence on cognitive, structural, and pedagogical dimensions. A key contribution of the reviewed literature is the identification of shared structural principles between music and mathematics, such as rhythm, proportion, symbolization, and patterns, which facilitate the creation of effective pedagogical links.

Furthermore, educational experiences integrating both disciplines, ranging from multisensory programs to innovative initiatives such as escape rooms or digital activities, are associated with improved conceptual understanding and increased student motivation, creativity, and engagement in the learning process. Despite these findings, it is important to note the heterogeneity of the results. Some studies report clear and positive effects, whereas others demonstrate modest or limited impacts at the symbolic level.

Future research should further examine the relationship between various forms of musical interaction (e.g., instrumental practice, rhythm training, or multisensory activities) and specific mathematical competencies, as well as how these relationships differ according to educational level and sociocultural context. Expanding research beyond dominant geographical and linguistic contexts and incorporating mixed-methods approaches that integrate cognitive, pedagogical, and classroom-based evidence will further enhance this field.

Although this review is constrained by linguistic limitations and the methodological diversity of the included studies, the available evidence suggests that the integration of music and mathematics is a promising interdisciplinary approach to education. This approach has the potential to enrich the teaching and learning processes, particularly when aligned with inclusive, meaningful, and creative educational goals.

Ethical approval

This study does not require ethics committee approval as it does not involve human, animal or sensitive data.

Author contribution

Study conception and design: KV; data collection: KV; analysis and interpretation of results: KV, AA; draft manuscript preparation: KV, MA, SS. All authors reviewed the results and approved the final version of the article.

Source of funding

The authors declare the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

Etik kurul onayı

Bu çalışma insan, hayvan veya hassas veriler içermediği için etik kurul onayı gerektirmemektedir.

Yazarlık katkısı

Çalışmanın tasarımı ve konsepti: KV; verilerin toplanması: KV; sonuçların analizi ve yorumlanması: KV, AA; çalışmanın yazımı: KV, MA, SS. Tüm yazarlar sonuçları gözden geçirmiş ve makalenin son halini onaylamıştır.

Finansman kaynağı

Yazarlar, çalışmanın herhangi bir finansman almadığını beyan etmektedir.

Çıkar çatışması

Yazarlar, herhangi bir çıkar çatışması olmadığını beyan etmektedir.

REFERENCES

Akın, A. (2025). Let me make mathematics and music together: A meta-analysis of the causal role of music interventions in mathematics achievement. *Educational Studies, 51*(4), 386-404. https://doi.org/10.1080/03055698.2023.2216826

Alam, A., & Mohanty, A. (2023). Music and its effect on mathematical and reading abilities of students: Pedagogy for twenty-first century schools. In D. A. Karras, S. K. Oruganti, & S. Ray (Eds.), *Interdisciplinary perspectives on sustainable development* (pp. 342-346). CRC Press. https://doi.org/10.1201/9781003457619-67

Azevedo, S., Rato, J., & Caldas, A. C. (2020). Contributo da formação musical no desempenho académico e cognitivo de crianças e adolescentes: Uma revisão sistemática. *Revista Portuguesa de Educação, 33*(2), 116-135. https://doi.org/10.21814/rpe.18506

Balasubramanian, K. (2021). Symmetry, combinatorics, artificial intelligence, music and spectroscopy. *Symmetry, 13*(10), 1850. https://doi.org/10.3390/sym13101850

Bergee, M. J., & Weingarten, K. M. (2021). Multilevel models of the relationship between music achievement and reading and math achievement. *Journal of Research in Music Education, 68*(4), 398-418. https://doi.org/10.1177/0022429420941432

Bergee S., & Ghorai, G. (2024). An approach to lagrange's theorem in pythagorean fuzzy subgroups. *Kragujevac Journal of Mathematics, 48(*6). https://doi.org/10.46793/KgJMat2406.893B

Bussu, A., & Mangiarulo, M. (2024). Playing music together: Exploring the impact of a classical music ensemble on adolescent's life skills self-perception. *PloS One, 19*(7), e0306326. https://doi.org/10.1371/journal.pone.0306326

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589-597. https://doi.org/10.1080/2159676X.2019.1628806

Ciabattoni, F. (2022). The harmony of the spheres and Dante's Paradiso. *Textual Cultures, 15*(2), 255-280. https://doi.org/10.14434/tc.v15i2.35544

Cheek, J. M., & Smith, L. R. (1999). Music training and mathematics achievement. *Adolescence, 34*(136), 759-761. https://n9.cl/v9erg

Crabtree, S., Hsu, M.-H., Pool, J., & Odell-Miller, H. (2025). Music Therapist's use of singing, listening, playing instruments and movement with music to improve cognition and reduce neuropsychiatric symptoms in music therapy for people living with dementia, *British Journal of Music Therapy, 39*(1), 5-19. https://doi.org/10.1177/13594575251327948

Cubarsi, R. (2024). Partition entropy as a measure of regularity of music scales. *Mathematics, 12*(11), 1658. https://doi.org/10.3390/math12111658

Da Silva, E. Dos Santos Baldin, M., & Dos Santos, F. (2017). Cognitive effects of numeracy musical training in Brazilian preschool children: A prospective pilot study. *Psychology & Neuroscience, 10*(3), 281-296. https://doi.org/10.1037/pne0000098

Di Stefano, N., & Spence, C. (2022). Roughness perception: A multisensory/crossmodal perspective. *Attention, Perception, & Psychophysics, 84*(7), 2087-2114. https://doi.org/10.3758/s13414-022-02550-y

Dignam, C. (2024). Harmonies on the string: Exploring the synergy of music and STEM. *International Journal of Technology in Education and Science, 8*(3), 491-521. https://doi.org/10.46328/ijtes.571

Ferrada, D. (2020). Algunas reflexiones sobre la crisis del modelo en la educación chilena a propósito del estallido social. *Revista Ecociencias, 10,* 4-10. https://n9.cl/gcmmq

Forgeard, M., Winner, E., Norton, A., & Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. *PloS one, 3*(10), e3566. https://doi.org/10.1371/journal.pone.0003566

Foster, C. (2013). Mathematical études: Embedding opportunities for developing procedural fluency within rich mathematical contexts. *International Journal of Mathematical Education in Science and Technology, 44*(5), 765-774. https://doi.org/10.1080/0020739X.2013.770089

García-García, J., Martínez-Artero, M. R. N., & Olivares-Carrillo, P. (2024). Exploring the influence of musical training on mathematical creativity. *Thinking Skills and Creativity, 52*, 101498. https://doi.org/10.1016/j.tsc.2024.101498

Gripton, C. (2023). Pattern in early years mathematics curriculum: A 25-year review of the status, positioning and conception of pattern in England. *Research in Mathematics Education, 25*(1), 3-23. https://doi.org/10.1080/14794802.2021.2010237

Hassan, B. (2023). Artistic resilience in times of crisis: Navigating adversity through creativity. *Journal of Religion and Society, 1*(2), 31-43. https://www.islamicreligious.com/index.php/Journal/article/view/25

Harney, K. (2020). *Integrating music across the elementary curriculum*. Oxford University Press. https://doi.org/10.1093/oso/9780190085582.001.0001

Hanif, A., Butt, A. I. K., Ahmad, S., Din, R. U., & Inc, M. (2021). A new fuzzy fractional order model of transmission of COVID-19 with quarantine class. *The European Physical Journal Plus, 136*(11), 1-28. https://doi.org/10.1140/epjp/s13360-021-02178-1

Hernandez-Olivan, C., & Beltrán, J. R. (2023). Musicaiz: A Python library for symbolic music generation, analysis and visualization. *SoftwareX, 22,* 101365. https://doi.org/10.1016/j.softx.2023.101365

Hicks, A. (2022). Music and the pythagorean tradition from late antiquity to the early middle ages. I. Caiazzo, C. Macris, & A. Robert (Eds.), *Brill's companion to the reception of Pythagoras and Pythagoreanism in the Middle Ages and the Renaissance* (pp. 82-110). https://doi.org/10.1163/9789004499461

Incógnito, O., Scaccioni, L., & Pinto, G. (2022). The impact of a music education program on meta-musical awareness, logical-mathematical, and notational skills in preschoolers. *International Journal of Music Education, 40*(1), 90-104. https://doi.org/10.1177/02557614211027247

Jian, Z. (2022). Sustainable engagement and academic achievement under impact of academic self-efficacy through mediation of learning agility-evidence from music education students. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.899706

Kang, M. (2024). *A study on Korean art song tradition with emphasis on vocal works by female composers: Hanbyeol Kang, Wonju Lee, Soon-Ae Kim, and JaeEun Park* [Doctoral dissertation, The University of Arizona]. https://repository.arizona.edu/handle/10150/675571

Kazantseva, A. V., Enikeeva, R. F., Toropova, A. V., Zakharov, I. M., & Ismatullina, V. I. (2023). A replication study of genetic variants associated with high-level musical aptitude. *Research Results in Biomedicine, 9*(2), 181-190. https://doi.org/10.18413/2658-6533-2023-9-2-0-3

Khatin-Zadeh, O., & Hu, J. (2024). The role of mathematical semiotic signs in enhancing working memory and inhibition as the components of executive functions. *Integrative Psychological and Behavioral Science, 58*(1), 138-148. https://doi.org/10.1007/s12124-023-09776-x

Lingefjard T., & Hatami, R. (2020). The beauty of abstraction in mathematics. *Policy Futures in Education, 18*(4), 467-482. https://doi.org/10.1177/1478210319895104

López, M. B., Haut, C. I. C., Masot, M. C. B., & Rodriguez, V. Z. (2021). Canciones infantiles para aprender matemáticas. *Campo Abierto, Revista de Educación*, *40*(1), 103-118. https://revista-campoabierto.unex.es/index.php/campoabierto/article/view/3546

Lovianova, I., Kaluhin, R., Kovalenko, D., Rovenska, O., & Krasnoshchok, A. (2022). Development of logical thinking of high school students through a problem-based approach to teaching mathematics. *Journal of Physics: Conference Series, 2288*, 012021. https://doi.org/10.1088/1742-6596/2288/1/012021

Ribeiro, F. S., & Santos, F. H. (2017). Enhancement of numeric cognition in children with low achievement in mathematic after a non-instrumental musical training. *Research in Developmental Disabilities, 62*, 26-39. https://doi.org/10.1016/j.ridd.2016.11.008

Ribeiro, F. S., & Santos, F. H. (2020). Persistent effects of musical training on mathematical skills of children with developmental dyscalculia. *Frontiers in Psychology, 10*, 2888. https://doi.org/10.3389/fpsyg.2019.02888

Trgalová, J., & Tabach, M. (2023). Affordances of virtual learning environments to support mathematics teaching. *Digital Experiences in Mathematics Education, 9*(3), 444-475. https://doi.org/10.1007/s40751-023-00127-4

Maldonado, E. (2024). Musical education in Kindergarten. Importance on the quality of life in children. *Health Leadership and Quality of Life, 3*(463). https://doi.org/10.56294/hl2024.463

Manila, B. (2020). Pedagogical content knowledge in music education among public elementary teachers. *IOER International Multidisciplinary Research Journal, 2*(3), 1-9. https://doi.org/10.54476/iimrj330

Merikoski, J., Haukkanen, P., & Tossavainen, T. (2019). Arithmetic subderivatives and Leibniz-additive functions. *Annales Mathematicae et Informaticae, 50*, 145-157. https://doi.org/10.33039/ami.2019.03.003

Nisha, K. V., Devi, N., & Sridhar, S. (2022). Music to ears in hearing impaired: Signal processing advancements in hearing amplification devices. In A. Biswas, E. Wennekes, A. Wieczorkowska, & R. H. Laskar (Eds.), *Advances in speech and music technology: Signals and communication technology* (pp. 217-236). Springer. https://doi.org/10.1007/978-3-031-18444-4_11

Parncutt, R., & Hair, G. (2018) A psychocultural theory of musical interval: Bye bye Pythagoras. *Music Perception: An Interdisciplinary Journal, 35*(4), 475-501. https://doi.org/10.1525/mp.2018.35.4.475

Piñero Charlo, J. C., Ortega García, P., Román García, S., & Geelan, D. (2021). Formative potential of the development and assessment of an educational escape room designed to integrate music-mathematical knowledge. *Education Sciences, 11*(3), 131. https://doi.org/10.3390/educsci11030131

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372.* https://doi.org/10.1136/bmj.n71

Ramos, A. (2022). *Teaching mathematics in primary education through music*. http://riull.ull.es/xmlui/handle/915/28786

Ruth, N., & Müllensiefen, D. (2021). Survival of musical activities. When do young people stop making music?. *Plos One, 16*(11), e0259105. https://doi.org/10.1371/journal.pone.0259105

Schlaug, G., Norton, A., Overy, K., & Winner, E. (2005). Effects of music training on the child's brain and cognitive development. *Annals of the New York Academy of Sciences, 1060*(1), 219-230. https://doi.org/10.1196/annals.1360.015

Spiro, R. (2025). *Schooling and the acquisition of knowledge.* Routledge eBooks. https://doi.org/10.4324/9781315271644

Szűcs, T., & Juhász, E. (2023). The role of music education in childhood. *Acta Educationis Generalis, 13*(2), 30-49. https://doi.org/10.2478/atd-2023-0012

Szirony, G. M., Burgin, J. S., & Carolyn Pearson, L. (2008). Hemispheric laterality in music and math. *Learning Inquiry, 2*, 169-180. https://doi.org/10.1007/s11519-008-0034-4

Trienekens, S., Escobar Campos, J. C., Schutte, L., & Bremmer, M. (2024). Who has access to a career in Western classical music? Building a tool to evaluate intersectionality in barriers to music education and careers. *Research Studies in Music Education*, *46*(3), 388-403. https://doi.org/10.1177/1321103X231224229

Yang, H., Ma, W., Gong, D., Hu, J., & Yao, D. (2014). Un estudio longitudinal sobre la experiencia de formación musical infantil y el desarrollo académico. *Scientific Reports, 4*(1), 5854. https://doi.org/10.1038/srep05854

Yang, W., Shen, L., Huang, C. F., Lee, J., & Zhao, X. (2024). Development status, frontier hotspots, and technical evaluations in the field of AI music composition since the 21st century: A systematic review. *IEEE Access, 12*, 89452-89466. https://doi.org/10.1109/ACCESS.2024.3419050

Zhao, S. (2024). The role of artificial intelligence in personalized music teaching quality evaluation. *Journal of Computational Methods in Sciences and Engineering, 24*(6), 3723-3733. https://doi.org/10.1177/14727978241297010

Zimmer, S. (2022). *Three essays on the economics of human capital* (Publication No. 29207543) [Doctoral dissertation, George Mason University]. ProQuest Dissertations & Theses Global. https://n9.cl/ibypy