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Research article

Music education as part of the STEAM model: A systematic review

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Abstract: The aim of this systematic review is to examine the possibilities of incorporating music education into STEAM education. The review was conducted and reported in accordance with the PRISMA statement and examines the ways in which music is used as part of STEAM and the role of music in STEAM processes across different educational contexts. A systematic search was carried out in January 2025 in four databases: EBSCO, Scopus, Pro Quest Social Science Premium Collection, and ScienceDirect. The inclusion criteria comprised peer-reviewed articles, dissertations, and empirical studies published in English between 2015 and 2025 that addressed educational contexts from primary school to higher education and incorporated music education within a STEAM context. Exclusion criteria included studies involving children under primary school age, pedagogical texts, conference presentations, therapeutic contexts, research without musical activities, and publications before 2015. Seventeen studies were selected for the extraction phase, two of which did not fully meet the eligibility criteria: one involved preschool-aged students and one was not peer-reviewed. Due to the limited number of available studies, these were included because they addressed musical activities within STEAM in a school context. The data were analysed using thematic and theory-informed qualitative synthesis, drawing on frameworks of interdisciplinarity, pedagogical integration, and aesthetics. The results indicate that music can be integrated into STEAM in multiple ways, including music theory learning, playing, singing, composing, and bodily musical expression. The role of music ranged from a motivational element supporting learning to a phenomenon under study within the STEAM process. However, not all music-related activities identified in the reviewed studies included aesthetic or creative expression, and the heterogeneity and limited number of studies constrain the generalisability of the findings. The review was not registered.

Keywords: interdisciplinary teaching and learning, music education, PRISMA, systematic review, STEAM

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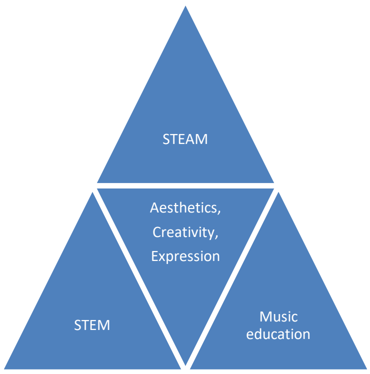

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1 Introduction

The purpose of this systematic review is to explore opportunities for implementing interdisciplinary teaching, STEAM (science, technology, engineering, arts, mathematics), in the context of music education. STEAM is an interdisciplinary model (Andreotti & Frans, 2019; Cheng et al., 2022; Liao, 2019), which aims to develop the 21st century learning skills like creative thinking and co-operation (Herranen et al., 2021). In the Finnish primary and secondary school curricula, music education focuses on the same elements as STEAM. Teaching collaborative skills and creativity forms the core of the Finnish music education (Finnish National Agency for Education, 2014, 2019). There is a global interest in STEAM and its possibilities in education (Belbase et al., 2022). Therefore, it is important to also explore the possibilities of music education as part of the STEAM process.

In the studies included in this systematic literature review, music education was positioned as a form of creative, aesthetic or musical activity within STEAM teaching. Creative activity and imagination develop the ability to interpret things and solve problems (Plonczak & Goetz Zwirn, 2015). According to Plonczak and Goetz Zwirn (2015), creativity and imagination are essential qualities in scientific research. The inspiration of an artist can be understood as analogous to a scientist's effort to solve a problem. Aesthetics is not limited to the arts but also plays a meaningful role in other fields. Through aesthetic expression, art enables alternative ways of interpreting phenomena—approaches that can also inform other forms of understanding. (Plonczak & Goetz Zwirn, 2015) Aesthetic experience also adds meaning to science learning (Mun, 2020) and is an essential part of music education (Reimer, 2022, pp. 7–8; Swanwick, 1988, 1992 pp. 2–3, 1). There is little research on integrating musical activity into the STEAM process, especially from a perspective where musical activity includes aesthetic expression.

In previous studies, Johnson-Green et al. (2020) have argued that STEAM teaching should pay attention to the interaction between subjects during the design phase. There should also be space and opportunities for creative expression. (Johson-Green et al., 2020) Johnson-Green et al. (2020) present a model integrating music with STEM (science, technology, engineering, and mathematics) subjects. In that study, an interdisciplinary environment was designed by representatives of different disciplines and professions. Careful planning and consideration of the learning objectives of each subject was conducted to achieve a balanced learning experience. In the process, students also worked on artistic and aesthetic issues alongside STEM fields. The results were promising, as students were able to utilize STEAM, cognitive, and socio-emotional skills in their learning (Johnson-Green et al., 2020). Similarly, Quingley and Herro (2016) highlight the design of the STEAM process in such a way that art is not just a project alongside science, but rather a tool for creative thinking. The role of art is not simply to be a presentation at the end of the process, but with good design, it expands problem-solving methods to be creative and innovative throughout the STEAM process (Quingley & Herro, 2016).

Combining the creative process and aesthetics with STEM subjects requires planning and considering each subject equally. There is a risk that the focus in the STEAM model is often the product, and the creative process is overshadowed. (Perignat & Katz-Buonincontro, 2019) When arts, aesthetics, or humanities are combined with STEM subjects, all subjects should be equally important (Liao, 2016; Silverstein & Layne, 2010). The following section examines the intersections between STEAM and music education.

1.1 STEAM and music education

Defining the acronym STEAM is ambiguous (Mejias et al., 2021). In particular, the role of the arts ("A") within this disciplinary configuration has been interpreted in diverse ways. The A in STEAM can mean many things: arts, aesthetics, or even generally all (Herranen et al., 2021; Perignat & Katz-Buonincontro, 2019), humanities or body expression (González-Martín et al., 2024). There are also studies examining whether STEAM developed from STEM or whether it is a completely new approach. Stroud and Baines (2019) state that the acronym STEAM can be considered a combination of arts and STEM (Stroud & Baines, 2019). According to Rodrigues- Silva et al. (2023) STEAM is not simply an evolution of STEM, but it is a completely unique way of integrating STEM subjects with the arts and creative thinking. (Rodrigues-Silva et al., 2023)

In the STEM field real- life phenomena are explained through scientific explanation. In STEAM, a scientific explanation includes an expressive or aesthetic perspective that enables a multidimensional interpretation of the issue. (Ramsey, 2022; Beguette & Beguette, 2012) Creative expression opens opportunities for the arts to become integral to the STEAM process. Approaching learning through an aesthetic, artistic, or creative process creates space for the arts within STEAM education. Music education is grounded in the understanding that musical expression inherently includes an aesthetic dimension (Reimer, 2022, pp. 7–8; Swanwick, 1992, pp. 1).

However, despite the central role of aesthetic and creative expression in music education, there remains a risk that music-related learning activities may exclude the individual's own interpretation and aesthetic experience. This risk emerges when the learning process prioritizes the acquisition of knowledge or technical skills, leaving little room for personal creativity and aesthetic expression (Swanwick, 2012, pp. 1–2). Aesthetic expression in action connects the individual's emotional world with lived experience, deepening engagement and meaning in learning (Reimer, 2022, pp. '121).

As stated above, one way to interpret the A in STEAM is aesthetics. Because aesthetics is an important part of music education, it is also essential to explore it in more detail as part of the STEAM model. A Korean study investigated the importance of aesthetic experience as a motivator for science learning (Mun, 2020). The study's premise was that the arts, as part of a STEAM entity, are more than just an occasional art lesson during science learning. Mun (2020) highlights a problem with design thinking, which has led to a mindset in STEAM as producing something through a design process. This product-centric mindset has shaped the way STEAM is thought of as an activity of "making". Mun (2020) states that aesthetics increases students' interest in science and technology learning and emphasizes the importance of understanding the differences in thinking styles across disciplines (Mun, 2020). Similarly, Perignat and Katz-Buonincontro (2019) highlight the same problem of focusing more attention on the product itself than on the creative process (Perignat & Katz-Buonincontro, 2019).

Among music education scholars, Swanwick (2012) has highlighted how aesthetic music education brings depth to the experience, where the individual's own history and previous experiences take on new meanings in different contexts. This does not mean the repetition of mechanical information, but meanings that have already been formed. (Swanwick, 2012) In line with Swanwick (2012), Reimer (2022) emphasizes the importance of aesthetics in music education and highlights experience-based learning as an important part of music education (Reimer, 2022). The ideas of Swanwick (2012), Reimer (2022) and Mun (2020) intersect in their emphasis on the aesthetic dimension of learning. Mun (2020) argues that design thinking in STEAM education is problematic because aesthetic experience adds dimensions to learning that go beyond the acquisition of knowledge, such as emotional engagement. (Mun, 2020). Similarly, Swanwick and Reimer emphasize that the aesthetic dimension is central to music education, and that mechanical skills or theoretical knowledge alone are insufficient (Reimer, 2022; Swanwick, 1988, 1992, 2012).

Interaction between different subjects varies in the STEAM process (Rodriques-Silva & Alsina, 2023). According to Klein (2017), the variation in interaction between disciplines can be divided into multidisciplinary, interdisciplinary and transdisciplinary. Only interdisciplinarity and transdisciplinary refer to activities that cross scientific boundaries. Multidisciplinary by contrast, involves the juxtaposition of disciplines while their boundaries remain intact, whereas transdisciplinary involves a deeper level of interaction in which disciplinary boundaries become blurred. (Klein, 2017, 2021, p.1-7) Mejias et al.'s (2021) theory refines this perspective by providing an instrumentalist framework for assessing the equality and pedagogical nature of disciplines in the STEAM process (Mejias et al. 2021).

Mejias et al.'s definition is based on the combination of instrumentalism and pedagogical view. It focuses on how the “A” is positioned in relation to the STEM disciplines and outlines four dimensions: (1) one-sided instrumental and non-pedagogical, (2) mutually instrumental and non-pedagogical, (3) one-sided instrumental and pedagogical, and (4) mutually instrumental and pedagogical. If the STEAM education is pedagogical and one-sided instrumental, this means that the action is not co-equal and one discipline is subservient to another. Non-pedagogical aspects connected to one-sided instrumentalism or mutual instrumental have no educational goals. In a mutually instrumental pedagogical setting STEAM disciplines are co-equal and learning objectives apply to all subjects, both within and across subject boundaries. (Mejias et al., 2021)

Mejias et al.'s (2021) theory shares similarities with Klein's (2017) framework. Both sets of definitions distinguish between different perspectives on disciplinary relations, focusing on how disciplines interact with one another. Klein's (2017) framework is not situated solely within a pedagogical context or limited to STEAM education. It presents a general categorization of interdisciplinarity. (Klein, 2017) In contrast, Mejias et al.'s (2021) model integrates both instrumental and pedagogical perspectives as part of the structuring of STEAM activities. (Mejias et al. 2021)

Klein's (2017) notion of multidisciplinary can be aligned with the one-sided instrumental and pedagogical, as well as the one-sided instrumental & non-pedagogical dimensions in Mejias et al.'s. (2021) framework. Similarly, Klein's (2017) concept of interdisciplinarity corresponds to the mutually instrumental and pedagogical dimension identified by Mejias et al. (2021). In both frameworks, disciplinary interaction involves the integration of sciences across established boundaries. (Klein, 2017; Mejias et al., 2021)

In the mutually instrumental and non-pedagogical setting described by Mejias et al. (2021), disciplinary boundaries no longer define the interaction, although disciplinary elements are still combined, generating new meanings. This perspective is comparable to Klein's (2017) definition of transdisciplinary, in which disciplinary boundaries are dissolved, and action emerges from beyond any single discipline (Klein, 2017; Mejias et al. 2021) Klein's (2017) interdisciplinary term is suitable for Mejias et al.'s (2021) mutually instrumental & pedagogical section. In both definitions, there is a mixing of sciences across scientific boundaries. In Mejias et al.'s (2021) mutually instrumental & non-pedagogical setting, there are no scientific boundaries, but the mixing occurs, creating new meanings. This is comparable to Klein's definition of transdisciplinary, where scientific boundaries are broken and action takes place from the perspective of other than a specific discipline. (Klein, 2017; Mejias et al., 2021)

The significance of the arts, aesthetics, and their intrinsic value in learning must therefore be recognized. Eisner (1998) argues that art teachers should never be required to justify the importance of their subject in terms of its relevance to students' academic achievement. While the skills developed through the arts are distinctive and may also influence academic outcomes, Eisner emphasizes the centrality of aesthetics and the uniqueness of art itself. He stresses that arts education should be valued for its own sake rather than as a means of promoting academic competence, noting that the educational value of the arts is jeopardized when their goals are defined primarily in terms of academic performance. The skills learned through the arts are unique, and some also affect academic outcomes. However, Eisner (1998) emphasizes the importance of aesthetics and the uniqueness of art, and the importance of teaching art precisely for its own sake. He writes about the importance of arts education for its own sake rather than for the promotion of academic competence. According to him, the importance of arts education in teaching is jeopardized if its goals are defined through the promotion of academic competence (Eisner, 1998).

1.2 Research questions

The aim of this study is to investigate the possibilities of music education in the implementation of STEAM teaching. Music education is strongly influenced by cultural practices, and it cannot be described as a single practice that is repeated everywhere in the same way (Kertz-Welzel, 2018). There are many ways to implement both STEAM and music education, so this study aims to highlight the working practices of STEAM as part of music education from primary education to higher education. The aim of this systematic literature review was to answer the following questions from the articles selected for the study:

1. How can music be used as part of STEAM education?
2. What is the role of music education in STEAM?

2 Methods

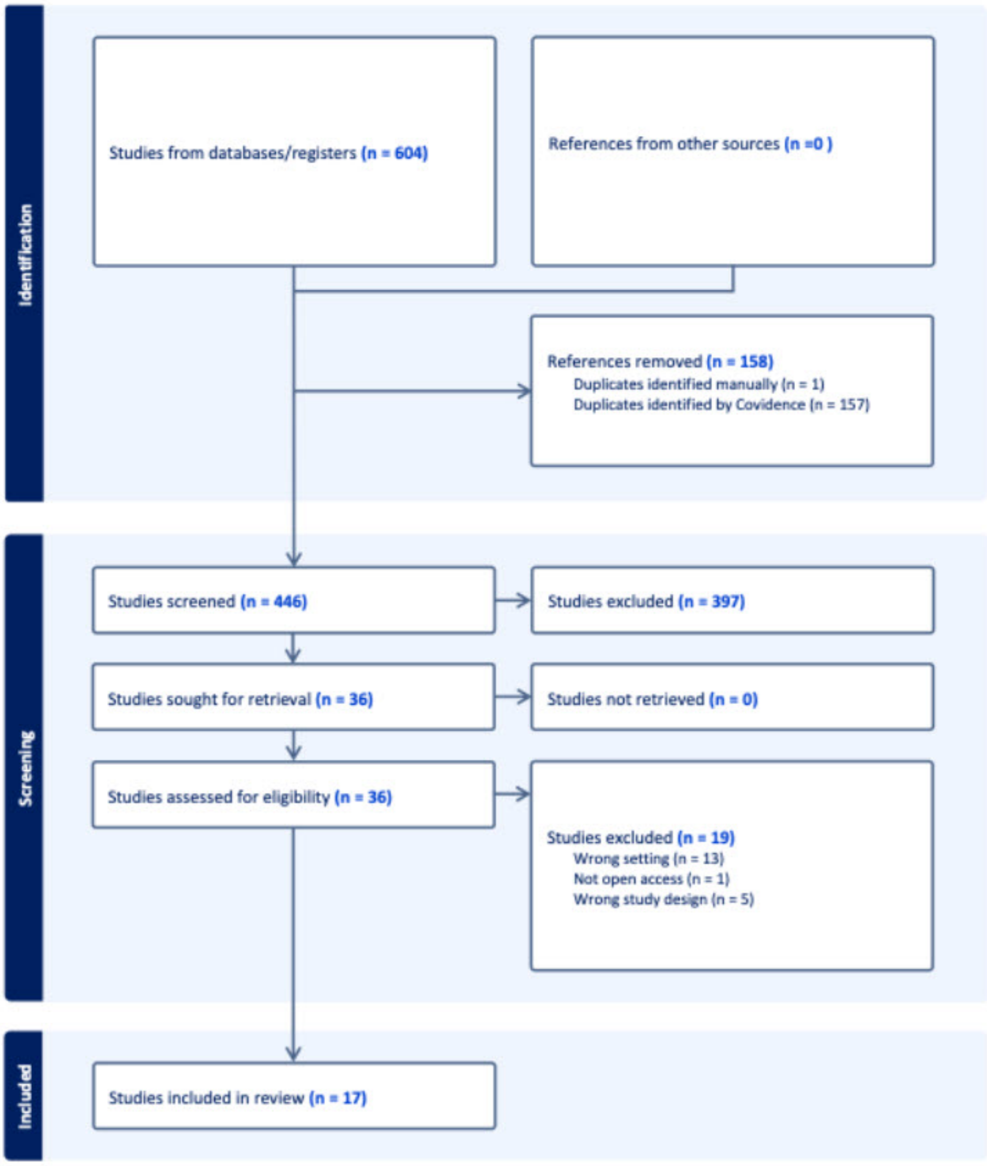
This systematic literature review was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Page et al., 2021). With the exception of two studies, all other studies selected for the literature review met the inclusion criteria (1) covered educational contexts from primary to higher education, (2) focused on the integration of music activities into STEAM, (3) were published in English, (4) were peer-reviewed and (5) the publication date was from 2015 to 2025. In one study, half of the children were preschool-aged, but the study was still included in the review process, because it was implemented in an educational context. The second study did not meet the criterion that the publication should be a peer-reviewed scientific publication but was an educational experiment. The article clearly described the learning process of the educational experiment and used technology to combine the study of music and mathematics in a school context. The publication had a factual bibliography, from which it was possible to check the sources used in the report. Since it included, in addition to mathematics, technology, and design, musical activity in the form of studying theory, the study was selected for analysis. In the article selection process, we excluded all studies that (1) did not include music activities as part of the STEAM process, (2) pedagogical texts, (3) conference presentations, (4) were in a therapeutic context, (5) were published before 2015 and (6) the study was conducted with children under school age.

Of the 17 studies included in the review, which met the eligibility criteria above, 14 were qualitative and three mixed method studies. There are few publications on combining music and STEAM. Due to limited data, the study age range is broad, from primary school to university level. All the chosen studies were empirical and concerned with activities taking place in educational work. No formal risk of bias assessment tools were applied due to qualitative and heterogeneous nature of the selected studies.

Articles were retrieved primarily from Ebsco, Pro Quest Social Science Premium Collection, Science Direct and Scopus databases. The dates when the searches were made and the number of results discovered by the search string are: (1) Ebsco databases, 28.1.2025, (Eric, Ebsco host, Open dissertations, and EBSCO academic e-book collection), 147 research results, (2) Scopus, 29.1.2025, 175 research results, (3) Pro Quest Social Science Premium Collection, 29.1. 2025, 185 research results, (4) Science direct, 29.1.2025, 138 research results. The eligibility criteria presented above served as a limitation in the data search. The search string was (Ebsco, Scopus and Pro Quest Social Science Premium Collection): “music* AND (STEM OR STEAM) AND education AND (math* OR computat* OR science OR technolog* OR engineering OR arts)”. The search string for the Science Direct database was: “music AND STEM AND STEAM AND education”.

Using Boolean operators, the search expression produced a more specific result. For example, using the AND operator at the beginning of the search expression produced a more specific search result. Before exporting the searches to Covidence, the first author manually removed 41 duplicates.

Figure 1. Prisma flow diagram.



Note. This Figure presents the phases in screening articles.

The studies were screened using Covidence software. As seen in Figure 1 above, the search string resulted in 604 publications from databases, and 158 were duplicates. All 604 publications were imported into the identification section in Covidence, and 446 studies were chosen for the screening. During the first screening phase, only the title and abstract were examined. The first author invited the third author to review the searches generated by the search phrase. Conflicts were solved after each screening phase. In some texts, Google Translate was used to translate the text from English to Finnish. From a methodological perspective, the reliability of the study could have been strengthened by a more comprehensive joint analysis of the selected articles.

After abstract and title screening, 37 studies remained for full-text screening. During the full-text review, the first author reviewed the articles in more detail and presented the articles she had rejected and the reasons for it to the third author. The rejection was based on the exclusion criteria. Seventeen studies were included in the extraction phase. The entire article review process was done in the Covidence software, and all articles were available for reading there. Both reviewers, the 1st and 3rd authors, used Covidence's include and exclude options during the reading process.

The first author was responsible for the analysis of articles and data collection. All authors discussed and provided feedback on the work as the process progressed. The authors' native language is Finnish, and all articles are in English, so this may pose a risk of misunderstandings. The Google Translate service was sometimes used for translation. The risk of bias is reduced by using eligibility criteria throughout the review process. This improved data management and helped select the right articles for research analysis.

The entire data was used in the analysis phase, and the perspectives to be investigated as defined by the research questions, were examined from the entire data. The thematic synthesis is based on the material and the concepts presented in the theory section: aesthetics, musical activity as a developer of creativity, and relationships between disciplines.

In this systematic literature review, concepts of musical activity, music education, aesthetic expression, creativity, and inter-science relations were used systematically to ensure conceptual consistency throughout the process. Musical activity was not assumed to inherently include aesthetic expression or creativity; instead, the concept of musical creative activity was used to explicitly denote musical engagement that also involves aesthetic dimensions. The conceptualization of inter-science relations was informed by Klein's (2017) framework, which distinguishes between multidisciplinary, interdisciplinary, and transdisciplinary approaches. As the use of the terms interdisciplinary and multidisciplinary in the reviewed literature was inconsistent, a single, clearly defined interpretative framework was adopted for this study to support analytical clarity (Klein, 2017).

The results of the data analysis are divided into two parts. The first part 3.1 reports how music has been integrated into the STEAM process, and this result is analysed from the perspective of interaction between sciences. The second part 3.2 interprets the data from the perspective of the role of music in the STEAM process. The interpretation is first made on a general level of musical activity without distinguishing the prevalence of aesthetic activity. The interpretation of results is deepened by also examining the aesthetic expression of musical activity. The most important points of the results are presented using italics font.

In this study, aesthetic expression as a form of creativity is linked to the following activities: composing, listening, singing, playing an instrument, and embodied music expression. The publications selected for the literature review do not describe musical learning processes in such detail that it would be possible to directly conclude whether they are aesthetic activities. However, the studies describe how things are learned, and based on this, learning situations that require the acquisition of knowledge, such as studying music theory, are classified in this analysis as activities that do not include aesthetic or creative activities.

3 Results

The possibilities for musical activity in a STEAM that emerged from the literature review studies were *studying music theory, playing, singing, listening, composing, and bodily musical expression.* The articles selected for this systematic literature review, which are presented in Table 1 below, included music activities alongside scientific observations and problem-solving processes. In all selected studies, the project was carefully designed collaboratively. Music educators designed the music activities to be included in the STEAM process together with other experts and teachers.

Table 1. Studies selected in the extraction phase.

Author/Year	Database	Article Title	Aim of study
(Andreotti & Frans, 2019)	Ebsco, ProQuest, Scopus	The connection between physics, engineering and music as an example of STEAM education	Reinforcing concepts typical of physics with iMuSciCA and how the program supports the understanding of processes by connecting them to other disciplines, such as technology and music.
(Azaryahu et al., 2023)	Science Direct, Scopus	Development of creative thinking patterns via math and music	The study examined the effectiveness of learning patterns in mathematics and music using the MusiMath intervention program.
(Cheng et al., 2022)	Ebsco, Scopus	Design My Music Instrument: A Project-Based Science, Technology, Engineering, Arts, and Mathematics Program on The Development of Creativity	The study examines the effectiveness of a project-based STEAM program on the development of creativity.
(Crowther et al., 2023)	Ebsco	Teaching science with the “universal language” of music: Alignment with the Universal Design for Learning framework	Combining active, constructivist, sociocultural, and case- or problem-based learning approaches with science learning and music.

(Eramo et al., 2024)	Scopus	The sound of science: A sonification learning experience in an Italian secondary school	The study explored the potential of sonification in science learning.
(González-Martín et al., 2024)	Scopus	Music and mathematics: Key components and contributions of an integrated STEAM teaching approach	The research developed operating models that combine mathematics and music for STEAM teaching.
(Johnson-Green et al., 2020)	Ebsco, ProQuest, Scopus	A Musical Perspective on STEM: Evaluating the Eco Sonic Playground Project from a Co-equal STEAM Integration Standpoint	The study examined the equal integration of subjects in STEAM activities with a shared common musical goal.
(Kim & Chae, 2016)	Ebsco, ProQuest	The Development and Application of a STEAM Program Based on Traditional Korean Culture	The study examined a traditional Korean musical instrument integrated into a STEAM program with high school students.
(Lavy, 2023)	Ebsco, ProQuest, Scopus,	Leveraging the Pied Piper Effect – The Case of Teaching Programming to Sixth-grade Students Via Music	The study examined teaching programming to sixth-grade students using the Melody Code application.
(Mannone et al., 2024)	Ebsco, Scopus	Music-driven geometric and topologic intuition: a case study with the Klein bottle	The study analyzed composition students' first encounter with the Klein bottle.
(Milne & Calilhanna, 2019)	Scopus	Teaching Music with Mathematics: A Pilot Study	The study aimed to improve learning outcomes in both mathematics and music.
(Montiel et al., 2024)	Scopus	Assessment of mathematical learning in a musical composition workshop applying tools from the onto-semiotic approach	In the study, composition students used mathematically based compositional tools. Mathematics students explored these tools within a compositional context.
(Mygdanis & Papazachariou-Christoforou, 2023)	Ebsco, Scopus	Exploring the integration of maker culture activities in the theory of music course at a Greek conservatoire	The study examined how to teach music theory using technology.
(Özer & Demirbatır, 2023)	Ebsco, ProQuest, Scopus	STEAM-based music activity example for gifted students: I design my instrument with Scratch and Makey Makey	The study examined how gifted students experienced and perceived the process of STEAM-based music activities.
(Roberts & Horn, 2024)	Ebsco, ProQuest, Scopus	Computational musicking: music + coding as a hybrid practice	The study explored how composing and coding can be learned through the Tune Pad application.
(Tuan & Kuo, 2023)	Ebsco	The Chant of Joy Dadaocheng": A STEAM Program for Art-Talented Students	In the study, students investigated their local environment by combining creativity, diverse ways of thinking, problem solving, and communication.

(Ward et al., 2018)	Ebsco	Songwriting to learn how high school science fair participants use music to communicate personally relevant scientific concepts	Experimenting with the Song writing to Learn model in STEM subject teaching

Note. This list describes the aim of study, year, and authors of the articles selected for the literature review.

3.1 Interaction between sciences and musical activities

In the articles discussed in this literature review, *the use of music in STEAM subjects ranged from motivating learning to enabling the interpretation of information through musical properties and supporting individual aesthetic expression in the learning process*. This section examines the interaction between sciences and the activity models presented in this research publication, where musical activity is part of the STEAM process. For example, Eramo et al. (2024) investigated the potential of data sonification in education. In their study, music was used as a tool for science learning. The meanings of music and sound were in the visualization of data, and musical creative expression did not occur even though students made their own pieces using technology designed for sonification. In their study, music as a sound source was used as a tool for science learning (Eramo et al., 2024). When music functions as a learning tool or facilitator of learning in another subject or discipline, this is, according to Mejias et al's theory, a one-sided instrumental and pedagogical position (Mejias et al.,2021). From the perspective of Klein's (2017) interdisciplinary theory, such a situation, if one discipline is subordinate to another but there is no interaction between the disciplines, it is a multidisciplinary activity. (Klein, 2017; Mejias et al. 2021)

In a few studies, students' work with music involved *familiarization with musical instruments and their characteristic sounds* (Cheng et al., 2022; Özer & Demirbatır, 2023). Cheng et al. (2022) and Özer & Demirbatır (2023) research follows the mutually instrumental and pedagogical definition of Mejias et al. (2021) theory. In the project, the student had to consider musical issues in addition to the physical properties of sound and other technical issues, and the working phase included analytical listening and testing of the sounds. It is noteworthy that neither subject was in a subordinate position to the other. (Cheng et al., 2022; Mejias et al., 2021; Özer & Demirbatır, 2023) Considering Klein's (2017) theory, Cheng et al.'s (2022) and Özer & Dermirbatir (2023) research is placed in an interdisciplinary activity, where interactivity was created between disciplines. (Cheng et al., 2022; Klein, 2017; Özer & Demirbatır, 2023)

In the Tuan and Kuo's (2023) and Kim and Chae’s (2016) studies, students' activities included *playing instruments and learning cultural elements* as part of a STEAM project (Kim & Chae, 2016; Tuan & Kuo, 2023). In the activity section of Kim and Chae’s (2016) study, students examined the characteristics of an instrument and made their own bamboo flute, the danso, which is a typical instrument of Korean culture. The activities also included playing the flute and preparing a concert. (Kim & Chae, 2016) In Tuan and Kuo's (2023) study, students collected experiential information about the Dadaocheng district through various cultural visits. Based on these experiences, they constructed a drama in which music was used to enliven the atmosphere. (Tuan & Kuo, 2023) These two studies varied between one-sided instrumental and pedagogical and mutually instrumental and pedagogical activities. Interaction between disciplines did not involve continuous integration across all phases. For example, in the analysis of flute playing technique, musical thinking and physics intertwined (Kim & Chae, 2016; Mejias et al., 2021) None of the articles included in this literature review fall into the categories of one-sided instrumental and non-pedagogical or mutually instrumental and non-pedagogical. In other words, each study distinguished between different disciplines, and all activities took place within a pedagogically guided environment.

In all other studies, included in this literature review, the interaction between disciplines was either multidisciplinary or interdisciplinary (Klein, 2017). This means that, the boundaries between disciplines were recognizable, and the level of integration was sufficient to describe the relationship as interactive rather than fully integrated. In one study, Andreotti and Frans (2019) students were provided with a well-designed technical application, through which, for example, mathematical and musical thinking intertwined, creating the possibility for transdisciplinary learning to be realized (Andreotti & Frans, 2019; Klein, 2017).

3.2 The ways music is used as part of STEAM Education

As discussed above, music can be integrated into STEAM from different perspectives. Sometimes *music can serve as a motivational activity for studying science, or music can be seen as a form of creative, aesthetic expression, sufficient as a learning experience*. Table 2 below describes the opportunities for combining STEAM and music education that emerged from the literature review. Table 2 also describes the types of musical activities that are found in the studies. The processes included *music theory learning, playing an instrument, singing, composing, listening and embodied music expression*. The projects combining science and music described in Table 2 are presented in more detail in the next section.

Table 2. Operating models combine musical actions and STEAM.

Reference	Learning music theory	Singing, Listening, playing	Composing	Embodied music expression
(Andreotti & Frans, 2019)	Music was learned through technology			
(Azaryahu et al., 2023) (González-Martín et al., 2024)	Music analysis			Interpreting music through body movement
(Cheng et al., 2022)	Designing a specific musical instrument with specific sound and scale characteristics (sound design)	Playing self-designed instruments		
(Crowther et al., 2023)		Music was integrated into science learning in the form of making or listening to music.		
(Eramo et al., 2024)			Processing sound as data “sonification” and combining it to describe processes in different scientific disciplines	
(González-Martín et al., 2024)	Music analysis			Interpreting music through body movement
(Johnson-Green et al., 2020)	Designing a specific musical instrument.	Playing and singing in a group.		
(Kim & Chae, 2016)	Music theory was learned through science and maker culture activities			
(Lavy, 2023)	The impact of music on learning to code was studied by having students code songs they chose themselves.	The students studied the melodies of the songs.		
(Mannone et al., 2024)			Musical thinking was visualizing the mathematical object “Klein bottle”. The Klein bottle was modelled using a musical metaphorical interpretation model.	
(Milne & Calilhanna, 2019)	Musical patterns like rhythm and meter			

	were taught through coding.			
(Montiel et al., 2024)			Mathematical students worked together with composition students.	
(Mygdanis & Papazachariou-Christoforou, 2023)	Music theory was learned through science and maker culture activities			
(Özer & Demirbatır, 2023)	Designing a specific musical instrument with specific sound and scale characteristics (sound design)	Playing self-designed instruments		
(Roberts & Horn, 2024)			The students were composing music via coding.	
(Tuan & Kuo, 2023)				The music was part of a project where students explored the culture and history of their local area.
(Ward et al., 2018)		Music was integrated into science learning in the form of making or listening to music.		

Note. This table describes the role of music in STEAM and ways to connect music to STEAM.

Most musical activities in the literature review articles are *activities related to the study of music theory*. (Andreotti & Frans, 2019; Azaryahu et al., 2023; Cheng et al., 2022; González-Martín et al., 2024; Johnson-Green et al., 2020; Kim & Chae, 2016; Lavy, 2023; Milne & Calilhanna, 2019; Mygdanis & Papazachariou-Christoforou, 2023) P*laying, singing, listening or composing* as part of the STEAM model was almost as common as the study of music theory (Cheng et al., 2022; Crowther et al., 2023; Eramo et al., 2024; Johnson-Green et al., 2020; Lavy, 2023; Mannone et al., 2024; Montiel et al., 2024; Özer & Demirbatır, 2023; Roberts & Horn, 2024). *Physical expression of music*, such as dancing or other musical movement, was clearly the least common (Azaryahu et al., 2023; González-Martín et al., 2024; Tuan & Kuo, 2023). Teaching and student activities were mainly carried out in a multidisciplinary or interdisciplinary manner (Klein, 2017). All studies fall within the scope of either the one-sided instrumental pedagogical or mutually instrumental pedagogical model. The subjects were therefore either on equal footing with each other, or one subject was a learning aid for the other. (Mejias et al., 2021)

Many studies used some application or technical device. The technologies used are presented here because they helped to integrate musical activity into the STEAM process, also in a way that combined creative and aesthetic expression with scientific thinking. The following Table 3 below consists of applications, used technologies, and their intended use in the articles that were chosen in the literature review. There were similarities between the technologies and, especially in the use of technological applications: Musical and scientific thinking occurred simultaneously, or it enabled the simultaneous existence of creative and scientific thinking. (Andreotti & Frans, 2019; Lavy, 2023; Roberts & Horn, 2024)

Table 3. Technologies used in the literature review studies and their intended uses

Technology used in the Study	Purpose of selected technology
Synth4kids software (Mygdanis & Papa-zachariou-Christoforou, 2023)	Music theory was explored through maker culture activi-ties using the Synth4kids software.
Makey-Makey interface (with Scratch) (Özer & Demirbatır, 2023)	Music theory was explored through maker culture activi-ties using the Makey Makey toolkit.
Xronobeat software (Milne & Calilhanna, 2019)	Mathematics was taught through music and Xronobeat.
IMuSciCA workbench (Andreotti & Frans, 2019)	The software combines mathematics, physics and music theory. IMuSciCA assisted in the design process of the instruments.
Tunepad (Roberts & Horn, 2024)	Students were learning musical elements and coding (Python) using the Tunepad application.
Melody Code application (Lavy, 2023)	Students were coding melodies.

Note. This table summarizes the technologies used in the studies selected for the literature review.

Teaching music theory through technology required the designer to familiarize themselves with the technology to be used and to carefully consider pedagogical approaches in advance (Andreotti & Frans, 2019; Lavy, 2023; Roberts & Horn, 2024). In these studies, technology served as a meeting point for different disciplines. The Greek study (Mygdanis & Papazachariou-Christoforou, 2023) succeeded in inspiring students to study music theory through the technology used in the classroom. In this study, there was interdisciplinarity in the activities and the pedagogical activity was mutually instrumental and pedagogical. (Klein, 2017; Mejias et al., 2021) *Music as a creator of mental images and a multidimensional means of interpretation* were highlighted in some of the studies (Azaryahu et al., 2023; Mannone et al., 2024; Montiel et al., 2024). Mannone et al. (2024) research used music and its figurative language to describe a Klein bottle to increase understanding of mathematically challenging structures. According to the study, such activities can contribute to the emergence of mathematical intuition (Mannone et al., 2024). These studies aimed for interdisciplinary activities. The students' learning process in these studies was shaped into interdisciplinary and mutually instrumental and pedagogical, for example through the solution of problems requiring examination from the perspectives of different sciences. (Klein, 2017; Mejias, 2021)

Azaryahu et al. (2023), in turn, studied the forms and variations of melody and their invention was combined with the invention of mathematical systematic systems, such as different number sequences. They discovered that creative thinking can be taught and promoted by combining art with mathematical thinking. (Azaryahu et al., 2023) Ward et al. (2018) presented a model for using song lyrics to promote science learning. To support science learning, *students wrote songs* and, in the process, learned both science and creative thinking and action. Their research aimed to create a personal relationship with science learning through music: Students made their own songs with lyrics about STEM subjects (Ward et al., 2018).

The position of software and technical equipment used in teaching varied. In some studies, the entire activity was based on software (Lavy, 2023; Roberts & Horn, 2024; Andreotti & Frans, 2019). A good example of such an activity was the software developed for musical instrument construction, IMuSciCA, which allowed students to virtually design different musical instruments (Andreotti & Frans, 2019). In the study, the software enabled evaluating the effects of varying material choices on sound without building the instrument with real materials. It was also quick and easy to experiment with different tunings. Based on the results, the IMuSciCa software also enabled simultaneous learning between music and physics (Andreotti & Frans, 2019).

In the Lavy´s (2023) study, musical and coding skills were developed as the project progressed. The teacher was constantly assisting with implementing the necessary commands in the Scratch program. The importance of music for coding was to provide meaningful content to coding in the research. The songs chosen for the study were well-known Jewish holiday songs, and through them, the students also learned about the culture in which the songs were set. (Lavy, 2023) Combining coding with music teaching required learners to know, for example, the time values and frequencies of the notes in the melody being coded. Mastery of music theory was also necessary when coding their own music. The software used and the coding skills needed were combined with music making in the lessons. (Milne & Calihanna, 2019; Roberts & Horn, 2024)

3.2 Aesthetic and creative activities as part of musical actions in STEAM

The role of music in STEAM ranged *from aesthetic and creative activities to internalizing theoretical knowledge*: Sometimes students worked solely on mathematical issues, and at other times the focus was on musical activities (Mannone et al., 2024; Montiel et al., 2024; Ward et al., 2018). There was also simultaneity, for example, when students tried to create a mathematical model of the melodies which they have created themselves (Azaryahu et al., 2023). It should be noted at this point that not all musical activities involved creative expression or aesthetics. These included, for example, the study of music theory or music history (Eramo et al., 2024; Lavy, 2023; Tuan & Kuo, 2023).

Azaryahu et al. (2023) demonstrated that music enhances *creativity during the learning process*. In the study by Azaryahu et al., students were free to create melodies. This activity included both aesthetic and creative elements. After the creative activity, the students´ task was to translate their melodies into mathematical form. Every student had the same task and each of them had to create a melody? At this stage, musical activity and mathematical thinking intertwined, but the musical activity had no creative or aesthetic dimension. (Azaryahu et al., 2023). M*usic motivated the learner* to study STEM subjects (Ward et al., 2018). In Ward et al. study, students were given the opportunity to use the creative production of music as an aid to science learning. They were given the opportunity to imagine and interpret phenomena related to cancer, for example, through music. This activity allowed the student to use both creative and aesthetic expressions as part of their own work. (Ward et al., 2018)

The STEAM *process increased creativity, motivation, and interest in STEM subjects through music* (Azaryahu et al., 2023; González-Martin et al., 2024; Özer & Demirbatır, 2023). González-Martin et al.'s study found that combining musical bodily expression and mathematics helped students interpret their own observations in a more diverse way. There was also freedom in physical expression to come up with their own interpretations, so students had the opportunity for creative and aesthetic activity. (González-Martín et al., 2024)

Some studies focused on *learning music theory through computational thinking*, project-based learning, and maker culture. The activities were implemented in a STEAM context and showed promising results by combining maker movement and hands-on activity with music theory learning. Students were actively engaged in lessons. Music was discovered and learned through STEAM activities. In the studies, the students' goal was to learn music theory, and their musical activities did not involve creative or aesthetic expression. Instead, their use of technology was associated with experimentation and invention. (Mygdanis & Papazachariou-Christoforou, 2023; Roberts & Horn, 2024)

In some studies, the role of music in the learning process was *to add joy and creativity to information and technology learning*. (Ward et al.,2018; Crowther et al., 2023) In the study by Crowther et al. (2023) *music was used to create a mood, a positive atmosphere*. This study examined the effects of listening to and composing music on learning STEM subjects. The results were promising and students gave positive feedback on the working methods in which musical activity had both aesthetic and creative elements, with music enjoyment as one example. Crowther et al. point out that implementing such projects requires professionalism from both the science and art teachers to ensure a balanced overall approach across subjects. (Crowther et al., 2023)

All articles in this review related to aesthetics are united by the opportunity for students to express things from their own world of experience. Mannone et al. (2024) used *the abstract and aesthetic nature of music as part of the learning process*. Their study explored the use of sounds and music to describe a mathematically demanding shape. Using music and sounds to describe the shape of a Klein bottle helped students engage with the shape in a deep and multidimensional way (Mannone et al., 2024). Eramo et al. (2024) studied how *science learning can be achieved through sonification*. The basic idea of sonification is to illustrate a thing or phenomenon by combining research information and sound in such a way that there is a logical connection between the two. In Eramo et al.'s (2024) study, vocalizing the data did not include much creative or aesthetic expression. However, students showed renewed enthusiasm for science and gave positive feedback about the collaborative group learning (Eramo et al., 2024).

4 Discussion

Music can be used as part of STEAM education in multiple ways, including studying music theory, playing, singing, listening, composing, embodied musical expression, and technology-mediated activities such as coding, instrument design, and sonification. In the studies reviewed, music served either as a motivator for science learning (Azaryahu et al., 2023; Crowther et al., 2023), a tool for interpreting information, or a form of creative and aesthetic expression in the STEAM process (Eramo et el.,2024; Mannone et al., 2024). In some studies, music and other disciplines were treated as equal learning factors (Tuan & Kuo, 2023), and in some studies, the role of music was more of an activity that supported science learning (Crowther et al., 2023). Overall, the findings indicate that while music has clear potential to make a meaningful impact on STEAM education, its educational impact is strongest when aesthetic and creative expression is explicitly integrated into the design of the STEAM process, rather than being limited to technical or theoretical activities.

The results of the study support previous STEAM literature, where music and the arts are seen as motivating learning and expanding thinking elements (Mun, 2020; Perignat & Katz-Buonincontro, 2019). At the same time, the results of this literature review extend previous research by showing that the role of music in STEAM processes varies from an instrumental support role to an equal and pedagogically meaningful integration, and that interactions between disciplines can occur in the activity, as described in the theoretical model of Klein (2017) and Mejias et al. (2021).

This study complements and refines the possibilities of combining music and STEAM on both an epistemological and pedagogical level, especially from the own starting points of music education. This literature review makes visible how music has been used as part of the STEAM process. This study does not define all musical activities as aesthetic by default but rather presents forms of creative and aesthetic expression separately. This problematizes STEAM processes in which musical activities do not include creative and aesthetic expression.

This systematic literature review includes only peer-reviewed studies and one research report from 2015-2025. This limits previous research and different types of publications to this study. In addition, only English-language publications have been selected, which may exclude some national or local STEAM models and practices. The contextual limitation of this study excludes all non-pedagogical contexts. Thus, for example, nonteaching STEAM experiments are completely ignored. The study data was heterogeneous, with varying target groups, teaching content and methods, which limits the generalizability of the results. Some studies had small sample sizes, which may affect the reliability of individual results. In addition, not all studies described musical activity in sufficient detail, which made it difficult to draw conclusions about the realization of aesthetic and creative expression. The results are based on thematic and theory-based interpretation, not quantitative meta-analysis.

This systematic literature review revealed that integrating musical activities with STEM subjects into STEAM requires time and resources from the responsible teachers in the project. In the future, it is important to research and develop models that promote creativity and aesthetics in STEAM. When it comes to assessment, it is important to consider *what* is being assessed. A science teacher may not be able to assess the achievement of the goals of a musical activity or vice versa. The articles combining STEAM and music education selected for the study revealed that there are a willingness and courage to combine different ways of learning creatively with scientific activities, and there is a desire to further develop this.

5 Conclusions

This systematic literature review examined the implementation of music education and STEAM subjects in the context of the educational field. Several methods and models emerged from the articles in this study, demonstrating the suitability of music for STEAM teaching. Planning and implementing teaching with interaction between sciences require time and resources, which can make implementation costly. Technology, from musical instruments to digital applications, also requires investment.

In most studies in this systematic literature review that combined music and STEAM, the activities were located at a multi- or interdisciplinary level, and truly transdisciplinary activities that cross scientific boundaries are rare. (Klein, 2017) The position of music in the STEAM process was often a tool supporting another subject, but in some studies, it was pedagogically an equal part of the whole (Mejias et al. 2021). Furthermore, examining STEAM processes through the aesthetic-experiential tradition of music education questions the importance of technically product-centric STEAM thinking and aesthetic expression therein.

Not all music-related activities, such as studying music theory or music history, are sufficient to provide quality music education. The role of music in STEAM education cannot be limited to activities that do not involve creative expression and aesthetics. Expressive power and aesthetic character in teaching are important in music education. Musical activities such as learning notes or studying music theory are important, but they do not form the core of music education. Notes become sound, and emotions can be expressed through music (Swanwick, 2012). Since combining music education and

STEAM is possible, it is essential to pay attention to ensuring that aesthetic and creative expression are part of the process already in the design phase.

Research ethics

In this literature review, an effort has been made to always refer to the original sources. The search term has been described as transparently as possible, and all information retrieval activities have been reported. The study has limited the perspective from which the publications selected for the study have been examined. This perspective has been presented as clearly as possible. The results have been presented as accurately as possible in accordance with the original sources. Referencing has not been done by distorting the original text or by removing the results from the original context.

Author contributions

Satu Korpi: conceptualization, investigation, methodology, project administration, writing, original draft preparation
Sari Harmoinen: Supervision, full text screening in the review process and review.
Katja Sutela: Supervision, full text screening in the review process and editing.

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