(Re)connecting music and ecology: teacher's knowledge and perceptions of an interdisciplinary approach for environmental education

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Abstract

Although in the past, Music and Ecology have been deeply intertwined, nowadays they do not usually cross pathways. In the process, great opportunities for their integration in educational settings have been lost, and, thus, their potential for promoting natural, cultural and social values. This research represents a meeting place between sciences and music, analyzing the historical connections between both subjects, contemplating the relationships of music with nature, and understanding music as part of the environment. Combining both quantitative and qualitative data from music teachers' surveys and interviews, a mixed-method analysis is presented addressing the main study dimensions: teacher's knowledge and training in the environmental field, and perception of music teachers about an interdisciplinary approach to the environmental issue. The empirical results of the triangulation, combined with the interdisciplinary theoretical framework, enable to establish didactic analogies between ecology and music, encouraging the re-connection of both disciplines and getting back a scientific approach to music and a musical approach to ecology.

Keywords

Music, ecology, environmental education, interdisciplinarity, creativity.

Statements and Declarations

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1 Introduction

Music, culture, and the environment have always been deeply intertwined. Numerous authors have explored the interplay among these three elements (Milesi, 2013; Allen, 2012; Ballard & Pandya, 2003), emphasizing that music is inherently linked to the natural environment, and any understanding of nature presupposes a cultural construct. As Pedelty (2012) argues, "drawing connections between music and the environment is a natural act. What is unnatural is to assume that music is somehow separable from the contexts in which it is created and consumed" (p.12).

Ecology highlights the necessary interrelationship between nature and culture (Milesi, 2013). Just as evolution is a biological adaptation to the environment, culture is a social and behavioral adaptation (Ballard & Pandya, 2003, p.164). Thus, variations among different cultures are closely related to their environments, and each culture has unique sensibilities derived from its interaction with the environment: "our interaction with the natural environment is of vital importance in how we express ourselves through folklore, art, religion, and customs" (p.164). Even Charles Darwin had a personal connection with music, analyzing it as a form of evolution (Monge-Nágera, 1998).

The current environmental crisis is intimately tied to a cultural crisis, where the arts and humanities, including music and ecomusicology, play a significant role in understanding these cultural dimensions (Allen, 2012). Ballard & Pandya (2003) also point out that "environmental degradation implies the degradation not only of natural systems but also of the cultural environment, as cultural conditions depend on the natural environment" (p.167).

The growing disconnect between music and the environment also has educational implications, as nature provides the opportunity to foster creativity in an improvised way (Freire, 2011). As this author suggests, in nature, children can interpret and perceive elements in various ways, so the interaction of music with the ecosystem enhances children's ability to play, imagine, dance, or create. In fact, Freire (2011) criticizes the idea that nature should be a concept to be learned; he believes that nature should be experienced, serving itself as a means of active learning, especially in the development of creative arts.

Music is part of the ecosystem because it constitutes a cultural element that is developed in relation to the environment and is deeply influenced by that environment. However, the progressive distancing between our current society and nature is causing these two elements to drift further apart, even in education. In this context, it is now more necessary than ever to understand the relationship between music and its natural ecosystem and actively promote it. As Pedelty (2012) points out, "if we want to protect the environment, we need to create cultural and ecological arguments, and if we want to preserve cultural traditions, we need to also recognize and evaluate their environmental impacts" (p.12).

This study investigates the relations between ecology and music and its didactic possibilities. Therefore, the main objective of the present research is to investigate how school teachers understand the didactic connections between ecology and music. To this regard, this work is based on the following research questions:

1. What are the didactic relations between ecology and music?
2. Do school teachers consider the connection between ecology and music?
3. What are their perceptions about this interdisciplinary proposal?
4. What are the main thematic axes around this approach?

In order to offer a holistic view on this subject, the connections between ecology and music are analyzed in the conceptual framework from a historical and didactic point of view.

2 Theoretical framework

2.1 Historical connections between music and science

Music and science have been historically connected in the education field, and different educational currents highlighting the hybridization between both disciplines are described in this chapter. According to Espinar Ojeda (2011), music has had a prominent role in the history of science, being interconnected with philosophy, medicine, mathematics, astronomy, ecology, or arithmetics (Espinar Ojeda, 2011). Therefore, to obtain a comprehensive understanding of the musical phenomenon and its historical implications in the science field, it is important to analyze how the connection between music and science gradually faded throughout the history of education.

Beginning with Classical Greece -due to its documentary and historical relevance to Western culture (Gertrudix Barrio & Gertrudix Barrio, 2011), music in this era was considered an element of nature and the cosmos that connected with *the* human (Matthews, 2013). In terms of education, the concept of music underwent a significant transformation during this time, transitioning from being considered an art emanating from the gods to being defined as a scientific discipline (Selhub & Logan, 2013), equating its study with that of all other sciences (Nasarre, 1700). There are numerous examples in Greek philosophical literature connecting music and science. The Pythagorean school studied music and arithmetics, using numbers to calculate astronomical and acoustic models, and also developed the theory of the harmony of the spheres (Arbonés & Milrud, 2017).Pythagoras developed the mathematical basis of music, dedicating to this thesis a significant part of his studies (Espinar Ojeda, 2011; Benedito, 1964). On the other hand, Plato defended music as a fundamental basis of education, studying its functions at both social and political levels (Matthews, 2013). Aristotle also described the interconnection and balance between the mind and the body through music, describing the use of different types of melodies according to their educational, spiritual, or conceptual functionality (Espinar Ojeda, 2011). Furthermore, according to this author, basic musical education in Ancient Greece was provided to all citizens to cultivate the soul and to promote moral and physical balance.

Moving on to the Middle Ages, music was considered one of the seven liberal arts, "called so because they are worthy to be learned by free and noble men" (Lorente, 1672, p.4). Specifically, music was integrated within the Quadrivium, which also included arithmetic, geometry, and astronomy (Arbonés & Milrud, 2017). Moreover, during this time, music was deeply connected to nature through the concept of *locus amenus* (Curtius, 1953), which involved the search for balance and harmony evoking paradise. In this sense, nature became a source of musical inspiration, emphasizing rhythms and repetitions that evoke natural cycles, as well as the universality of rhythmic and melodic patterns (Ledune, 2016).

Following the tradition of Ancient Greece, the Renaissance is marked by the importance of polymath thinkers who embraced the learning of diverse disciplines to make knowledge advance (Dail, 2013). It is worth noting the figure of Leonardo

da Vinci, who integrated knowledge of arts, science, and engineering (Kaufman et al., 2010), as "within this view of science, the arts helped to know and understand the world" (information omitted for reviewing procedure). In contrast, the figure of Galileo Galilei also stands out, playing an essential role in the transition to scientific positivism, characterized by a more experimental and modern scientific perspective, moving away from the philosophical and polymath perspective (Stefanov, 2017).

In the Baroque period, following the ideals of the time, the concepts of music and nature underwent a profound transformation, becoming imposing and dark elements that accompany individual suffering (Stefanov, 2017). Furthermore, numerous musical treatises continue to describe music as a science, highlighting a Neoplatonic conception intertwined with religiosity and positivism inherited from previous eras. Notable treatises include Nasarre's "Musical fragments" (1700) and Lorente's "The *why* of music" (1672), which states that "music is a science of perfect harmony and softness" (p.1). On the other hand, in contrast to the Baroque period, Classicism reintroduces the concept of *locus amenus*, once again focusing on the harmony and balance associated with music and nature (Stefanov, 2017). This is expressed by Cerone (1613) in his treatise "The Melopeo and Master": "we will conclude that there is nothing so friendly to nature, or that desires and covets so much, as Music (...) since it consists of proportions and harmonic temperaments" (p.157). This idea of proportionality brings music closer to disciplines such as arithmetic, geometry, or harmony. Thus, in the Enlightenment period, the foundations were laid for a scientific and naturalistic observation of the musical phenomenon. As Montes (2009) points out.

> Descartes, D'Alembert, Diderot, and Rameau study musical activity in animals and humans from a biological and physical perspective. Lamarck, in particular, examines music as a naturalist, even going so far as to consider the feats of a pianist in the same light as the long neck of giraffes, that is to say, as an argument about the evolution of species. (p.3)

However, it is precisely during this time that the study of music divides into two trends: on one hand, theoretical music as an object of scientific study, and on the other hand, music as a means of expression and subject of artistic study (Matthews, 2013). According to this author, this perspective evolved and persisted over time, culminating in the Industrial Revolution with a gradual distancing of human beings from nature, characterized by the exploitation and degradation of the natural environment. In contrast, it was also during this period that the romantic movement emerged, advocating for the role of the Arts as a means of individual expression and the connection of human beings with nature (Ledune, 2016). This laid the groundwork for the future development of educational trends in the 19th century that incorporated arts and nature as educational tools (Selhub & Logan, 2013), such as the *New School* developed by Francisco Giner de los Ríos (Otero Urtaza, 2013). However, the success of the Industrial Revolution values fostered a gradual separation between artistic and scientific interpretations of music that continues to the present day, as well as the compartmentalization of knowledge into increasingly specialized areas (Matthews, 2013).

In contrast, interdisciplinary approaches have begun to emerge in recent years, especially from the artistic field (Espinosa, 2006). This author describes how ecological movements related to music have gradually arisen, leading to profound

changes in musical aesthetics and also having scientific and social repercussions. Dail (2013) attributes the term "cultural polymathy" to this interdisciplinary phenomenon, likening it to the thinking of Renaissance polymaths who promoted the interconnection of various disciplines to enhance knowledge. However, these integrative perspectives between science and music are not predominant today, and "they are gradually being lost to an increasing specialization of subjects" (information omitted for reviewing procedure, p.113). Consequently, the historical connections that numerous thinkers have described between music and science throughout history are progressively fading away.

The historical overview addressed in this paper shows how music is not historically limited only to the realm of art and humanities but also encompasses philosophy and science. However, the convergence between music and sciences in education gradually weakened throughout history. Although the current educational system is distant from this interdisciplinary approach, the connections between music and science outlined by thinkers such as Pythagoras, Socrates, Plato, Aristotle, and Galileo still endure today.

2.2 From ecology and music to ecomusicology

The musical phenomenon doesn't solely encompass music itself but also includes the surrounding environment, places, people, and languages, forming an ecosystem in which everything is interconnected. Pedelty (2012) points out that social and environmental contexts are crucial when creating music, implying a communal construction whether through listening, dancing, online downloading, or musical performance. Therefore, as this author maintains, "ecological synthesis is not only important for achieving more sustainable music but also for understanding music in a more holistic manner, and thus comprehending what music is" (p. 12).

However, as seen in the previous section, contemporary society is increasingly disconnected from its natural environment, experiencing what Louv (2005) refers to as Nature Deficit Disorder. According to this author, the widespread lack of contact with the natural world to which we belong leads society to become increasingly detached from its surroundings and less sensitive to environmental issues. Milesi (2013) also explores how this phenomenon can extend to music, which also tends to be seen as increasingly separate from its surrounding environment: "By separating nature from culture, and consequently from society, modernity has regarded them as two distinct categories" (Milesi, 2013, p.11).

In a similar vein, Izaguirre-Roitegi (2014) argues that contact with nature provides students with opportunities to develop their imagination and creativity: "The freedom and the close relationship they find in this environment make them feel free, leading them, for example, to create games that depend entirely on the natural elements around them" (p.9). In this regard, Pedelty (2012) views music itself as a form of evolution:

> Music is a form of evolution, defining species. We make music because we can, because we express our humanity through musical sound, as well as through our connections with others and with a shared sense of belonging to a place. (Pedelty, 2012, p.11)

As described by Sanfeliu (2010), composers' inspiration from various elements of the ecosystem has been a constant throughout the history of music:

> Many works and creations from different artistic disciplines are remarkable for their relationship with the environment, ranging from the most catastrophic to the most hopeful. Artists propose reflective, critical works related to the environment, which is gaining more prominence. It's also worth noting that while many artists prefer to communicate their reflections on the environment individually, there are also others who have joined forces and created artist organizations to collectively promote environmental activism. (p.10)

This perspective gained particular importance in the history of music from the mid-20th century onwards, thanks to the emergence of new languages in contemporary music that explore the surrounding sound world through multiple listening and sound experimentation. During this period, sound ecology and the use of environmental sound elements to create awareness and facilitate the creative process began to be deeply studied (Bellodi & De Oliveira Fonterrada, 2007).

It was precisely during this period that a discipline specifically dedicated to analyzing the relationships between ecology and music, known as ecomusicology, emerged. This discipline is described as "the study of music, culture, and nature in all the complexities of those terms" and "considers musical and sonic issues, both textual and performative, related to ecology and the natural environment"(«Ecomusicology», 2013). As outlined by Harley (1996), the principles of musical ecology represent the foundation of this discipline, encompassing the relationships between music and the environment, the holistic perception of the musical phenomenon, as well as the application of ecological concepts to music, such as diversity or symbiosis. Linked to the growing concern about the environmental crisis, this concept continues to evolve, with numerous authors advocating for it as a discipline in its own right (Allen, 2012; Carrigan, 2013; Allen & Dawe, 2016; Pedelty, 2012; Titon, 2013).

The contributions of this discipline also have academic implications, emphasizing the importance of addressing environmental issues from an interdisciplinary perspective. In this regard, Allen (2011) points out that "environmental work has flourished in the sciences, but all academic fields have been ecological, including the humanities" (p. 391). Therefore, he calls for interconnection in classrooms between the concepts of music, sound, culture, society, environment, and nature. Similarly, Titon (2013) explores how ecomusicology can provide solutions to current issues related to music and sustainability, and Pedelty (2013) defines its use as an educational tool. As will be seen in the following sections, thanks to its communicative, artistic, and transformative potential, music can serve as a creative, aesthetic, emotional, and expressive medium for conveying environmental messages, as well as for informing, inspiring, and raising awareness (Carrigan, 2013).

2.3 Interdisciplinary ecologist movements: raising awareness through music

In a context strongly marked by technological advancement, the studies of Murray Schafer (1975) prompt reflection on the ecosystem of which we are a part and the

transformations it is undergoing, particularly in terms of sound. This author considers that "music is something that sounds" (Schafer, 1975, p.45) and defines noises as "sounds that we have learned to ignore" (Schafer, 1975, p.27). As stated in *The Rhinoceros in the Classroom* (1975), "the sonic environment of any society is an important source of information" (p.27). When we compare our current society with older societies, we quickly realize how the world has become increasingly noisy: "the uncontrolled proliferation of machines and technology, in general, has resulted in a worldwide soundscape or intensity that continues to increase" (p.27).

Based on this conception of the sonic phenomenon, in his work *The Tuning of the World*, Schafer (1977) introduces the revolutionary *soundscape* concept. For Schafer (1977), a "soundscape is any field of acoustic study" (p.23). Thus, the landscape is no longer solely analyzed from a visual aspect but also from a sonic perspective in which advocacy plays a leading role "by denouncing the degradation to which a particular place has been subjected" (Acuña Troitiño et al., 2003). This opens up the debate on sound pollution, which he presents as "one of the great contemporary problems of contamination" (p.27). In summary, soundscape can be defined as a "set of sounds from a specific environment, whether natural or artificial, from the past, present, or future" (França, 2011, p.38).

Following the path initiated by Murray Schafer in Canada, from the 1960s onward, other American authors such as John Cage, Morton Feldman, and Earle Brown also began to show an interest in soundscape, giving rise to an interdisciplinary environmental movement that soon spread to the European avant-garde (Espinosa, 2006). Specifically, composers like Pierre Henry, François Delalande, and Pierre Schaeffer were members of the *Group de Recherches Musicales* in Paris, focused on sound research. This movement encompasses visual, theatrical, musical, literary, and technological arts from an affective and emotional approach to education (Publicover et al., 2018). Sanfeliu (2010) describes this interdisciplinary interaction as follows:

> Artists from various disciplines, be it film, photography, dance, visual arts, sculpture, music, or eco-design (...), share their perspectives on the environmental reality. They are artists and activists simultaneously, driving initiatives with the conviction that one must engage with reality to transform it and achieve a sustainable common future. These artists give a voice to the planet and are motivated by their concern about the gravity of environmental issues. They seek to raise awareness about the need to respect and preserve it and to find new and innovative ways, through artistic language, to represent the changes that are happening (p.9).

Therefore, an unprecedented dialogue is established among different artistic disciplines, where all the Arts become closely connected to the natural and social ecosystem that surrounds them. In this context, John Dewey (1938) describes art as an experience, and the artistic object as a vehicle through which to have an artistic experience, interacting with individuals and the ecosystem, involving everything associated with art. Thus, painting, acoustics, technology, sound, and creation combine to produce natural and cultural products in which the sense of belonging and the education of sensibility for ethical and aesthetic development become particularly relevant (França, 2011).

In the same vein, Violeta Hemsy de Gainza (2010) points out the need to

integrate all living *languages* into music education, adapting the available means to the understanding of street actions and reflections. According to this author,

> Musical activities continue to be, as they have always been—although they may have changed in appearance over time—human, natural, inclusive, integrated, genuine, and easy! Choosing, sharing, developing, recording, and preserving these experiences, these practices is also something human, musical, natural, and easy!" (p.34)

Among other proposals, Hemsy de Gainza (2010) emphasizes the awareness of the sound environment, the handling and exploration of sound materials and objects, the development of auditory fantasy and imagination, and the integration of sound and music into interdisciplinary experiences that include other aesthetic or artistic fields.

On the other hand, the study of soundscape as a descriptive element of the ecosystem also brought up the reflection on noise pollution in music classrooms, appealing to the concept of *acoustic ecology* (Espinosa, 2006). Specifically, Schafer (1975) and Espinosa (2006) point out that all musicians should be concerned about noise pollution, considering that music teachers have an added responsibility when addressing this issue in the classroom from a positive and reflective perspective.

Therefore, the approach to noise pollution from the classroom "must be initiated by musicians since we are the architects of sounds. We are responsible for selecting and organizing interesting sounds to produce the desired aesthetic effects" (Schafer, 1975, p.27). Following the philosophy of this author, the concept of ecology considered in this work also encompasses reflection on the soundscape and analyzes noise pollution as an environmental issue in which music plays an essential role. Moreover, it also views pollution as a threat to the ecosystem's balance and emphasizes the importance of working sustainably for our environment to develop a global and active education.

3 Research design and method

3.1 Context

This research aims to analyze the knowledge and perceptions of music teachers regarding environmental issues and their treatment in the classroom from an interdisciplinary approach. This study was conducted as part of the doctoral thesis titled *Information omitted for reviewing procedure* [details removed for peer review] and presents the main results obtained on this matter.

The Autonomous Community of Galicia, where the research was conducted, is characterized by having a widely dispersed rural population that maintains close contact with nature. This natural and cultural heritage is expressed through music, which covers social, political, environmental, and identity-related themes, using elements from the oral tradition repertoire (Costa, 2004). These characteristics, reflecting the close synthesis between music and the environment, heritage, and identity, can be extrapolated to other regions, highlighting how nature directly influences artistic and cultural expressions, especially in music. Thus, we expect that the results obtained for our region can be enlightening for other places with similar characteristics.

In this context, this study aims to analyze how music teachers perceive the relationship between ecology and music at an educational level. To do this, a didactic-curricular investigation is designed to promote the reflective and critical attitude of teachers regarding their teaching work (Alcaraz, 2002; Acuña Troitiño et al., 2003)). Since ecology itself is not a subject in the curriculum of this region, it is analyzed from the perspective of environmental education, which is reflected as a cross-cutting theme to be addressed in all areas of knowledge. In this way, this research specifically studies the knowledge and perception of music teachers on how to integrate environmental education and music in the classroom. Thus, this study emphasizes the importance of creating educational tools that adapt to the specific needs and concerns of the school context and that can be effectively applied in the classroom (Cabrero, 1991).

With this objective, a mixed methodology combining quantitative (questionnaires) and qualitative techniques (interviews) is proposed. As Moscoso, (2017) points out, quantitative methods allow working with "large amounts of data seeking variations and statistical correspondences between various variables" (p.634), while qualitative methods are "based on the subjectivity of individuals and the individuality of situations" (p.634). Thus, the combination of both techniques seeks to obtain a comprehensive and contrasted view of the researched topic, fostering reflection and critical analysis on the research theme and offering a holistic view of it through the subsequent triangulation of quantitative and qualitative data. This approach, as highlighted by Pereira Pérez (2011), holds particular significance in the realm of social sciences, with a specific emphasis on its applicability within the educational domain.

Finally, it is important to note that this research also has a social activism dimension (Denzin & Lincoln, 1998) since the purpose of the study is not limited to understanding the current state of the researched topic but also has a social objective, addressing environmental values and ethical ideals that are relevant to the community. Specifically, this work aims to disseminate the researched topic among the study participants, who will then act as advocates within the educational community. The ultimate aim is for this information to catalyze the initiation of transformative steps towards a more interdisciplinary approach to education.

3.2 Research dimensions

Following the perspective of Manheim (1982), this work focuses on two fundamental dimensions to address the research problem posed regarding the interdisciplinary connections between ecology and music. On the one hand, music teacher's knowledge and training in the environmental field is analyzed as the first dimension. On the other hand, the perception of music teachers about an interdisciplinary approach to the environmental issue is studied as the second dimension. Manheim (1982) defines these dimensions as the minimum set of questions necessary to design a research project appropriately and comprehensively. The full research [details removed for peer review] examines two extra research dimensions: the presence of music as a tool to promote environmental awareness in the classroom, and the use of music as a resource for environmental awareness at school.

The first dimension aims to explore the proficiency and educational background of music teachers in Galicia regarding the environmental field, analyzing their

level of knowledge on ecological matters and regarding the application of music as a teaching ressource for environmental education. This dimension seeks to understand their concerns, limitations, needs and ideas regarding its practical implementation, helping to identify key opportunities.

The second dimension aims to study the influence and personal assessment that music teachers have regarding the interdisciplinary integration of music and ecology, as well as their perceptions about its impact among students. By means of this dimension, the strengths and drawbacks that educators identify in this interdisciplinary field can be examined, as well as their viewpoints concerning its usefulness, significance, and societal importance.

3.3 Data collection

The data collection process is designed regarding the different research phases according to the methodological approach presented. Subsequently, the process starts with a quantitative phase, addressing the delimitation of the study population and the selection of a representative sample, and continues with a qualitative phase in which sampling was conducted to select participants for the in-depth interviews. The quantitative data obtained in the first phase, as well as the qualitative data collected in the second, are analyzed in the following pages, and the results are defined concluding with a general interpretation of the data, allowing for a comprehensive analysis and understanding of the results.

Regarding the quantitative phase, the target population of the study is the ensemble of School Centers located in the Region of Galicia (Primary and Secondary School), which are listed by the Department of Education of the Xunta de Galicia. From the total of 1.409 educational centers, a representative sample of 303 centers was selected through simple random sampling, as shown in the Table 1 below. For this purpose, the sample was delimited based on various variables or strata, ensuring that all strata of interest are correctly and proportionally selected (Vivanco, 2005). The selected strata were three: the school level (Primary or Secondary), the location (province in which the center is stablished) and the geographic area (urban or rural).

Table 1 Distribution of the population and sample by educational levels

School level	Number of educational centers	Percentage of educational centers	Selected sample
Primary School	898	63.73%	193
Secondary School	511	36.27%	110
Total	1409	100%	303

Source: (information omitted for reviewing procedure)

Once the the sample was selected, the data were collected by a research questionnaire including a set of pertinent questions to determine the object of study in relation to its characteristics, variables, or dimensions (Bisquerra, 1989). The 40 items included were divided according to the research dimensions and combine all open-ended, multiple-choice and closed-ended questions. The questionnaire was reviewed by a group of four experts in various areas closely related to the research topic, and was sent to a pilot sample of five in-service teachers in order to ensure content validity and viability. In order to obtain the maximum number of responses, the questionnaire was sent to the schools with three reminders spaced over a month. The achieved participation rate represented

a 33.33% of the total sample, as a total of 101 responses were received from educational centers. This response rate can be attributed to the fact that this process was conducted in the last semester of the school year, a period when educational institutions are busier (information omitted for reviewing procedure).

Therefore, to delve more comprehensively into the subject of study, a qualitative phase was developed to seek information from informants regarding specific issues (Rodríguez Gómez et al., 1996). The interview protocol defined by Patton (2002) was selected as the best option to complement the information obtained from the questionnaires and to collect deeper information into the various dimensions of the research, maintaining flexibility during the interview process. The interview protocol was reviewed by a group of five different experts and it included 12 compulsory and 5 optional questions addressing experiences, behaviors, feelings, opinions, knowledge, and sensitivity regarding the research subject (Patton, 2002). A representative sample of 10 teachers was selected, and the sampling of the interviewees was conducted taking into account the representation of three criteria: gender, educational stage, and teaching experience. All the interviews were conducted individually in a range of 20 and 40 minutes, and a fully informed consent principle was accepted in each case.

3.4 Data analysis

Regarding the quantitative data obtained through the questionnaire, a statistical descriptive and inferential analysis was developed by using the IBM SPSS Statistics 25 Program (IBM Support, 2023). Measures of central tendency and dispersion were analyzed for the descriptive analysis of the variables. Contingency coefficients and Pearson correlation coefficients were calculated to analyze inferential statistics among the different variables.

Concerning data obtained from the interviews, a qualitative procedure was developed to organize and draw conclusions regarding the research dimensions. A detailed transcription recreating both verbal and non-verbal aspects of each interview was elaborated (Seidman, 1991), and a coding system was developed to "provide a space for thinking about the text and its interpretation" (Gibbs 2012, p.66). The MaxQDA Program (MaxQDA, 2023) was used to facilitate the coding process by identifying text segments and establishing categories and subcategories for inductive and deductive analysis.

4 Findings

Following the proposed methodological design, the results of the study are presented in two sections. In the first section, quantitative findings concerning the main results of the questionnaire are detailed. In the second section, qualitative findings revealing the conclusions of the interviews are listed. Both quantitative and qualitative findings describe the main results about the two dimensions covered by this study: music teacher's knowledge and training in the environmental field (Dimension 1), and perception of music teachers about an interdisciplinary approach to the environmental issue (Dimension 2).

4.1 Analyzing the Questionnaires: Quantitative Findings

4.1.1. Dimension 1: teacher's knowledge and training

To analyze music teacher's knowledge in the environmental field and training in the use of music as a didactic resource for environmental education (Dimension 1), seven items were considered in the questionnaire:

1. Previous knowledge in the environmental field
2. Interdisciplinary educational background between music and ecology
3. Training in specific thematical axes regarding music and the environment
4. Contributions of formal, informal and non-formal education in teacher's proficiency
5. Musical and environmental content relationships contemplated by teachers
6. Knowledge of specific educational initiatives
7. Teacher capacity to be educated in this subject

Regarding *previous knowledge of participant teachers*, previous knowledge in the environmental field was contrasted with previous knowledge in raising environmental awareness through music. The answers to the questionnaire revealed that a substantial proportion of the participating educators (77%), self-report possessing normal (3), good (4) and very good (5) degree of proficiency in the environmental domain. Conversely, a comparatively modest cohort, comprising 50% of the participating educators, assert having a normal (3) and good (4) degree of familiarity with the use of music as a pedagogical tool for environmental education.

Notably, Pearson correlation coefficient (0.470) was calculated and a Chi-squared test (0.001 significance) was conducted, revealing a direct correlation and a dependent relationship between these two variables, indicating that a higher prior knowledge in environmental education coincides with a higher familiarity with leveraging music as a resource for environmental consciousness. Of particular interest is the observation of an inversely proportionate relationship between age and the levels of prior knowledge in both subject areas. A negative Pearson correlation coefficient (-0.54) revealed that advanced chronological age tends to correlate with diminished prior knowledge in the aforementioned domains. However, it is pertinent to underscore that the statistical analyses undertaken furnish definitive evidence supporting the existence of a causal dependency between both variables.

Regarding the *interdisciplinary educational background* between music and ecology, a substantial majority of the participating teaching cohort (91.1%) reported never having received interdisciplinary training bridging both subject areas, with a mere 8.9% acknowledging having received such formation. These results are described in the frequency table (Table 2). In this case, the analysis of dependence and correlation conducted did not uncover statistically significant differences based on the age or years of experience of the teaching staff.

Table 2 Interdisciplinary educational background received by teachers

Interdisciplinary training		Frecuency	Percentage	Valid percentage
Valid	**No**	92	91,1	91,1
	Yes	9	8,9	8,9
	Total	101	100,0	100,0

Source: (information omitted for reviewing procedure)

The following section investigates the *training of the participating teachers in specific thematical axes* regarding music and the environment, revealing that generally participant teachers perceive their knowledge to be fair (2) or good (3). These themes encompass music in the animal world and ecology related to music obtaining the lower knowledge results (1-2), and biological functions of music and music and evolution achieving slightly higher knowledge results (2-3), as shown in Figure 1.

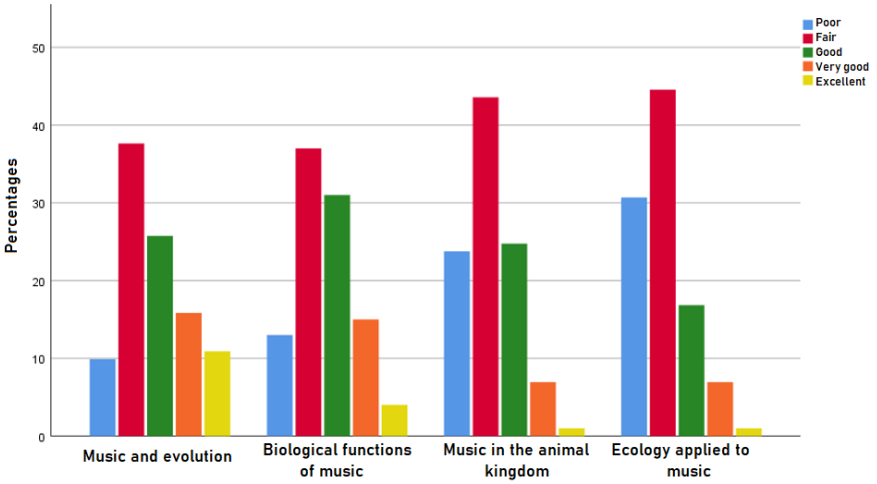

Fig. 1 Graphic representation of training in specific topics. Source: (information omitted for reviewing procedure)

The next section analyzes how *different types of education (formal, non-formal, and informal)* have contributed to the learning of the aforementioned topics. Informal education obtains the highest degree of contribution in teacher proficiency regarding the research subject since a majority percentage (69.3%) perceives this type of education as a pathway to acquire knowledge regarding the previously analyzed topics. The descriptive statistics display lower values regarding both formal and non-formal education.

Regarding *musical and environmental content relationships* taken into account by teachers, considering their educational background and prior knowledge, a majority percentage of the participant teachers, represented by 69.3%, contemplate the relationship between both issues, whilst only 30.7% consider that there is little to no relationship. However, when analyzing the level of k*nowledge regarding specific initiatives* addressing both content areas in education, there is predominantly limited knowledge, both within their educational institution (17.82%) and in other schools (3.96%) or outside the educational environment (13.86%). These specific initiatives primarily relate to the construction of instruments using recycled materials and to musical works related to environmental themes. Additionally, teachers also mention occasional activities related to noise pollution, the development of specific lesson plans on the topic, initiatives aimed at raising awareness such as concerts or festivals, and other initiatives such as collaboration with environmental organizations.

The final section examines the *teacher's capacity to educate in this subject* by analyzing teacher opinions regarding the level of preparedness that educators from different subject areas (music teachers, science teachers, other teachers, and

themselves) perceive they have for addressing the researched topic. The overall level of preparedness is generally low, with the “other teachers” category receiving the lowest ratings for preparedness, followed by the “music teachers” one. Conversely, the “science teachers” group is the highest-rated category in terms of preparedness, and the self-perception of preparedness is also relatively high.

Finally, a chi-square test was conducted to analyze the dependency between this variable and the variable of previous knowledge in the environmental field. The test results revealed that in the "music teachers", "other teachers" and "themselves" groups, the assessments of the level of preparedness in the researched topic depended on the teacher’s background in that specific area. However, the test values in the "science teachers" group, with significance levels above 0.05, indicated that the perception of the level of preparedness of science teachers in the researched topic was not dependent on their background in that area. These results align with the previous findings, which indicated that science teachers are best prepared and have more previous knowledge to address this topic in the classroom.

4.1.2. Dimension 2: perception about an interdisciplinary approach

To analyze the perception of music teachers about an interdisciplinary approach to the environmental field (Dimension 2), 6 items were considered in the questionnaire:

1. Perception about the social impact of this interdisciplinary approach
2. Music teacher’s concerns about environmental issues
3. Degree of interest in a didactic approach to ecology from music
4. Perception of the educational relevance of the research subject
5. Teacher’s perceptions about the reception of the subject by students
6. Teacher’s assessment of the didactic possibilities of the subject

Regarding the *perceptions about the social impact* of this interdisciplinary approach, the results reveal that this is a topic with a high social impact, as the majority of respondents (93.93%) provided positive assessments regarding the use of music as a resource for environmental awareness. The highest percentage (43.6%) is associated with a score indicating a high social impact, while the lowest scores consistently receive less than 4% of the responses.

The cross-tabulation chart (Figure 2) obtained when crossing this variable with the age of the participant teachers reveals an inverse relationship: the younger the teachers, the greater their perception of the social impact of the topic. This relationship was also confirmed through the Pearson correlation coefficient (-0.198) and the Chi-square test, both of which indicated a significant inverse dependency between the social impact of the topic and the age of the teachers. By crossing the data with Dimension 1 variables, a significant relation between the relationships of musical and environmental content contemplated by teachers and the perception of the social impact was observed.

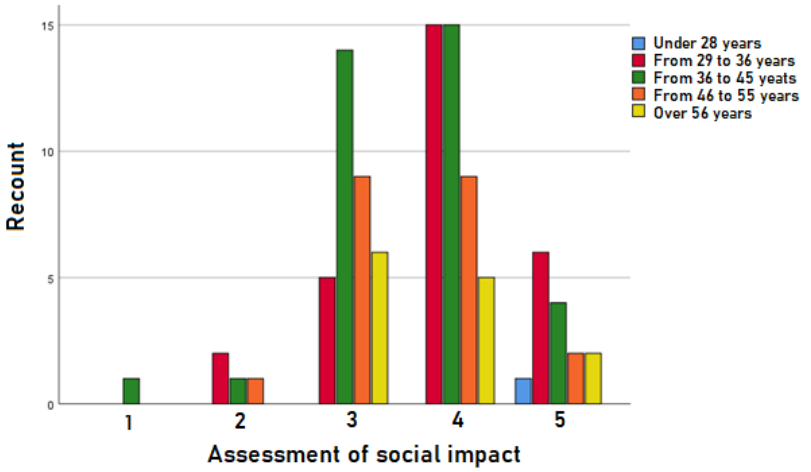

Fig. 2 Graphical representation of the cross-tabulation chart for the variable perception of the social impact depending on age. Source: (information omitted for reviewing procedure)

Regarding *music teacher's concerns about environmental issues* in their pedagogical approach, a substantial majority (83.2%) express apprehension regarding the promotion of environmental awareness, in contrast to a minority (14.9%) who do not share such concerns. Similarly to the previous variable, statistically significant dependencies were also observed between the concern for environmental issues and the age of the participating educators in the survey. This relationship, verified through the Chi-square test and the contingency coefficient, was also confirmed in relation to the previous variable, indicating a dependence between educators' perception of the social impact of the theme and their concern for it.

The next section analyzes the *degree of interest among participating music educators in understanding environmental issues* and how to address them within the classroom, using a scale ranging from 1 (not interested) to 5 (very interested). As depicted in the cumulative frequency graph (Figure 3), nearly half of the surveyed population (49.5%) expresses a high level of interest (4) in the didactic application of environmental issues and only a small residual group (3%), indicates no (1) or little (2) interest.

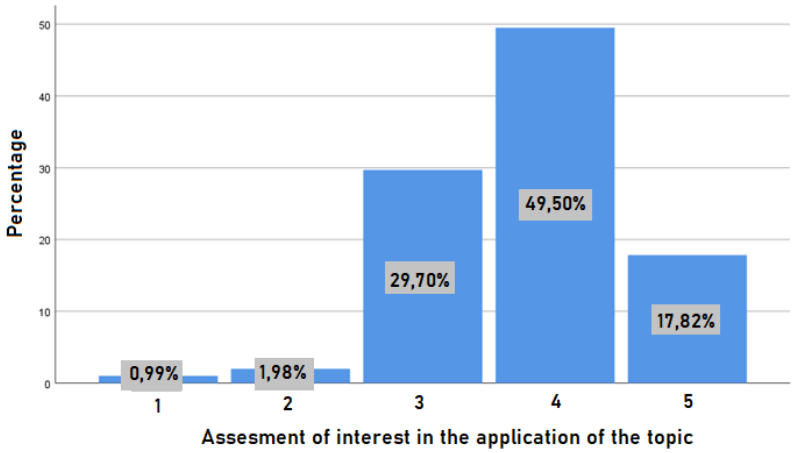

Fig. 3 Graphic representation of the assessment of the interest in the application of the topic. Source: (information omitted for reviewing procedure)

Furthermore, the presence of statistically significant dependencies of this variable were tested revealing a direct relation with age and a positive dependence relation with the educational level: the highest levels of interest in the didactic application of the theme were consistently observed within primary educational institutions versus secondary schools. In addition, a direct relation was observed between this variable and the perceptions about the social impact of this interdisciplinary approach, but no dependencies were observed regarding music teacher's concern about environmental issues. Hence, there is a segment of participating educators who, despite expressing concerns regarding environmental matters, do not manifest interest for incorporating these themes into their own pedagogy.

Regarding the *perception of the educational relevance of the research subjec*t, the majority of respondents (87.1%) believe it is necessary to incorporate environmental topics in the music classroom, whilst a minority (11.9%) do not share this belief. Concerning the specific environmental education activities that music educators would like to implement in the classroom, notable preferences include activities related to environmental values (9.71%), exploration of the natural environment (5.83%), creating instruments from recycled materials (2.91%), activities addressing noise pollution (4.85%), organizing festivals and concerts (2.91%) and analyzing songs related to the environment (1.94%).

The next section addresses *teacher's perceptions about the reception of the subject by students*, analyzed both in terms of their comprehension and their engagement. The descriptive analysis for both items exhibits remarkable similarity, indicating that educators hold a highly favorable perspective regarding both the extent of students' grasp and their level of engagement regarding the connections between music and the environment. Regarding the perception of students' comprehension of the research subject, the highest percentage (39.6%) is concentrated around high assessments of student understanding, while only a small percentage provides assessments of little understanding (8.9%) or no understanding (2%). Regarding the perception of students' active involvement within the research subject, the majority percentage (52.5%) is also centered on

high evaluations regarding student engagement, and only a small percentage provides assessments indicating low involvement (9.9%) or no involvement (1%).

To gain a comprehensive overview of this dimension, the following item examines *teacher's global assessment of the didactic possibilities of the research subject*. On a scale that ranges from 1 (not positive at all) to 5 (extremely positive), educators hold a favorable opinion regarding the effectiveness of the use of music as an educational tool for fostering environmental awareness. A substantial majority of the participating educators (42.6%) appraise the use of music as a didactic tool for environmental consciousness positively, followed by a significant percentage (27.7%) who regard it as very positive. It's also worth highlighting that the proportion of respondents expressing negative (5%) or very negative (1%) evaluations is quite minimal.

4.2 Analyzing the Interviews: Qualitative Findings

Qualitative analysis enables a deeper exploration of information concerning the previously examined aspects of Dimensions 1 and 2. Specifically, the findings resulting from the analysis of 887 coded segments across 10 interviews led to the identification of two categories directly associated with each dimension in our study. More precisely, the two categories linked to Dimension 1 encompass the conceptions of environmental education and the identification of environmental themes addressed through music. On the other hand, those related to Dimension 2 refer to music's contributions to environmental education and societal concern regarding this subject matter. This section provides an in-depth comprehensive description of each of these categories along with their corresponding subcategories.

Regarding the *conceptions of environmental education*, a total of 33 segments were identified in this category, which was described by 7 out of 10 of the interviewed teachers. To facilitate the analysis, these segments were organized into 4 distinct subcategories, as outlined in Table 3. As can be observed, the interviewees predominantly hold a view of environmental education that is centered on the teacher's role and a heightened sensitivity towards the natural environment. These subcategories encompass the largest number of segments and are mentioned by a substantial portion of the interviewed teachers. In contrast, a smaller group of interviewees expressed a perspective emphasizing emotional and personal connections, and only half of the interviewees focus on the civic dimension of environmental education.

Table 3 Codified segments in each subcategory regarding the conceptions of environmental education

Subcategories	Segments	Documents
Teacher-centered	12	7
Nature-awareness-centered	10	7
Emotional and personal connection-centered	8	4
Civic education-centered	5	5

Source: (information omitted for reviewing procedure)

Regarding teacher-centered conceptions, a majority of the interviewed teachers consider environmental education as "a cross-cutting theme" (E1), as "a subject that requires further in-depth exploration" (E10), as "an opportunity to acquire skills and competencies for understanding our surrounding" (E6) and "an issue

that should be addressed holistically across all subject areas" (E6). These approaches advocate for the presence of environmental education as a relevant interdisciplinary topic in the classroom, assisting students in recognizing environmental issues and finding solutions from all areas of knowledge: "I believe that I not only have to teach music but also teach music and connect it with the environment around me" (E2). Considering the nature-awareness-centered subcategory, interviewed teachers mainly emphasize the importance of understanding, perceiving, respecting, conserving and nurturing the natural environment. Interviewees also highlight the significance of "approaching students to real-life environmental scenarios or situations" (E7) and refer to ecological concepts such as *landscape, ecosystem, life cycle* or *resources*. These conceptions are directly linked with the emotional and personal connection-centered subcategory, considering the connections with the environment "not only at an environmental level but also on a personal and relational level" (E3). Within this subcategory, interviewees relate environmental education with sociocultural values such as personal motivation, culture, life quality, human needs and health. Lastly, a smaller group of the interviewed teachers contemplate environmental education as civic education-centered, considering the relevance of the subject for the community and the citizenship and "creating awareness so that children, in the future, become responsible, coherent, and committed citizens to the world they live in" (E4). Table 4 summarizes the most relevant and illustrative contributions from each subcategory.

Table 4 Teacher's testimonies for each subcategory regarding the conceptions of environmental education

Subcategories	Testimonies
Teacher-centered	*Environmental education, I believe, is something fundamental and should be a cross-cutting theme, not just dedicating it to a specific subject or occasional projec*t (E1).
	(Environmental education) *it's a pending subject that we need to delve into because it's clear that we aren't raising awareness among the students. (...) The environment is crucial, and they need to learn how to preserve it, and that should be taught at home as well as in school. It's an unfinished subject, but also something very important.* (E10)
	I think we need to discuss environmental education in a cross-cutting way across all areas (E6).
Nature-awareness-centered	*Environmental education is aimed at perceiving and understanding the environment that surrounds us, raising awareness of the need to preserve it, and making use of the resources it can offer us (*E6).
	For me, environmental education is about respecting our surroundings, our landscape (E2).
Emotional and personal connection-centered	(The environment) *is what keeps us alive on many occasions; it's a whole life cycle, and when we start to lack some of its links, everything deteriorates. So everything we can know, conserve, and take care of is important, it's important for our quality of life and for our perpetuation in the world, so to speak* (E7).
	I do it (environmental awareness) *out of personal initiative and because I enjoy it. In fact, as a musician always, and as a performer. I play the bagpipes, right? And I always think, "If someday I record an album, besides including my compositions,*

	there should be sounds of nature." It's something I like, so it's a somewhat personal matter (E5).
Civic education-centered	E*nvironmental education, I suppose, is a significant part of our civic education. In other words, if we want to take care of our environment, which ultimately surrounds us in every way, it inevitably has to be closely linked to our civic education* (E8). *For me, it's a bit about education, making us aware that we are not isolated individuals but that we live in an environment, and everything we do in it, so to speak, affects others and the environment itself* (E3).

Source: (information omitted for reviewing procedure)

The other category directly related to Dimension 1 is the *identification of environmental themes related to music*, by analyzing the specific topics that the interviewed teachers address regarding the connections between environmental and musical content. All the teachers referred to this category during the interviews, and a total of 125 segments, grouped into four subcategories, were identified. These subcategories organized these themes into biology-related, evolution-related, zoology-related and interdisciplinary-related.

The first subcategory, biology-related themes, includes references to the connections between music and the body, music and the brain and music and health, with special mentions to the negative effects of noise pollution. Teachers also emphasize the biological origins of the natural materials present in musical instruments (wood, metal, sand, wind, etc.), including references to material properties, their presence in the environment, and the crafting and manufacturing process directly connected to nature.

The next subcategory, evolution-related themes, compiles the testimonials of the interviewed teachers that identify connections between music and the environment at cultural and evolutionary levels. This includes references to the socio-environmental context of composers, the tradition and heritage of folklore as a link to the environment, and the values of coexistence and cooperation that music promotes as an evolutionary advantage. In this regard, several of the interviewed educators emphasize the emotional function of music from an evolutionary perspective, with references to environmental, diegetic, and incidental music.

Regarding zoological-related themes, participant teachers also relate music with animal calls and environmental sounds, considering their functions in the ecosystem and their connection with natural cycles. Teachers also indicate specific music works inspired by animal sounds, references to plants and trees mentioned in traditional songs, as well as ecosystems and natural elements present in music.

The last subcategory concerning the identification of environmental themes related to music is represented by interdisciplinary-related topics, which encompass references connecting music with science in the history of education. Specifically, interviewed teachers mention philosophical approaches to music and nature, the harmony of the spheres theory, the connections between music and mathematics, geometry, physics, or acoustics.

The following Table 5 provides a summary of the key and illustrative contributions from each of the aforementioned subcategories.

Table 5 Teacher's testimonies for each subcategory regarding the identification of environmental themes related to music

Subcategories	Testimonies
Biology-related themes	*Our subject is very interconnected in the sense that, even from the instruments we use, many times the materials come from the environment itself* (E2).
	(In my class) *I brought together the cycles of plant species because they are also important for making instruments* (E7).
	We can create elements to play instruments ourselves, using materials provided by the environment, such as wooden logs or sand, and so on (E6).
Evolution-related themes	*It's like folk music; city kids have to sing folklore. And if you don't teach it to them here, when will they learn it?* (E10).
	Hildegard of Bingen, for example (...), had a book about plants and her compositions., the polyphonic compositions, the Ordo virtutum (...) We also collaborate between the two departments and I talked about harmony, spirit, monastic gardens, and so on (E3).
Zoology-related themes	*The Carnival of the Animals, for example, very simple. I talk to them about the life of the animal we are working on (...) But first, they have to get to know the animal; I teach them about it, analyzing its habitat, whether it lives in groups, lives alone, what it eats, etc.* (E10)
	When we talk about symphonic poems, (I show the students) *the sounds of nature as evocative of a musical work or as inspiration for a musical work* (E3).
Interdisciplinary-related themes	*I work on mathematics through the topic of proportions. In other words, they (the students), in a cross-cutting way, ended up even giving me formulas, presenting formulas to me explaining why certain instruments and certain families ended up having the shape they had (...) We work on the shape of instruments, which influences the sound. And sound, well, it's related to acoustic physics* (E8).
	In class, we discuss the sounds of the planets, how each one inspired Halls (...), the character of each piece of music (...) the Platonic theory of emotions associated with certain music (E3).

Source: (information omitted for reviewing procedure)

To enhance the information about Dimension 2 (teachers' perception), the category derived from qualitative analysis, *contributions of music to environmental education*, enables a more in-depth exploration of how educators perceive the potential contributions of music to environmental awareness. This category, with 69 codified segments, illuminates several key dimensions of their perception:

- As a communication and sensitization resource: teachers mainly acknowledge the role of music as an effective means of communication and raising environmental awareness: "with music, you can achieve a multitude of outcomes, as music is something that greatly motivates children" (E9). The majority of the interviewed teachers (9 out of 10) mention how music serves as a communicative resource to reach a diverse audience and various age groups, having the capacity to generate impactful social slogans and transmit powerful societal values. They also consider music as a tool to

sensitize individuals by establishing emotional connections with the environment, promoting knowledge and environmental actions, advocating for flora and fauna conservation, encouraging social responsibility, promoting recycling and material reutilization and communicating environmental problems such as consumerism or noise pollution.

- As a reflective tool: music is recognized as a resource for fostering reflection among educators and establishing debates about acoustic pollution,songs lyrics addressing environmental issues, personal motivations, the contextual elements within songs, everyday life situations and other academic subjects and areas, providing a platform for contemplation on environmental themes and concerns.
- As a practical resource for internalizing content: this subcategory includes references considering music as a practical resource "tending to leave a more indelible impression than theoretical explanations or other forms of instruction" (E10). Half of the interviewed teachers view music as a useful tool to develop positive habits and educational practices, aiding in the absorption and comprehension of environmental concepts and values.
- As a resource for stimulating perception: music is perceived by educators as a resource capable of enhancing individuals' ability to notice and respond to environmental issues, facilitating their receptiveness to the natural environment and environmental cues and phenomena. Especially in urban contexts, they consider "the inspiration drawn from nature, its sounds, and its environment serves as a wellspring for both musical expression and personal expression" promoting heightened environmental perception.

Table 6 compiles the most significant testimonies from each of the previously explained categories.

Table 6 Teacher's testimonies for each subcategory regarding the identification of environmental themes related to music

Subcategories	Testimonies
As a communication and sensitization resource	*I believe that music can always help promote any topic. I think it's a fundamental means of communication that is also very close to youth culture. Well, it's relevant for youth and for all age groups* (E1). *I believe that music also works with emotions, sensitivity, and that work (...) in one way can also be something cross-cutting, something that can transfer to have that sensitivity and those emotions towards the environment* (E2).
As a reflective tool	(I try) *little by little to introduce fresh elements, even if they are not part of the subject's curriculum, but things that make them think, develop their own criteria, and enable them to disagree with me and their peers* (E8).
As a practical resource for internalizing content	*If I'm going to introduce any music that has something related to nature, I will explain it to them; I won't just present it and leave it at that* (E10). *In music classes, when we talk about something, we also try to discuss or surround the topic that the issue addresses* (E5).
As a resource for stimulating perception	*Through music, you can work on emotions, coordination, expression, vocalization – it's so important! Especially in younger grades, but also in the older ones; it's so important in their education for growth* (E10).

	In tutorials, they (the students) *work on (...) a reflection of the school, what's pleasant, what's unpleasant, what smells, what sounds, visually, how the elements of the school are, how the school makes them feel, which places in the school are the most pleasant or unpleasant. They work on everything related to their perception of the school, and from there, we start working* (E2).

Source: (information omitted for reviewing procedure)

The last category of the qualitative analysis addresses *societal concern regarding this subject matter* and enables to broaden the information regarding Dimension 2. The majority of the participant teachers (9 out of 10) show concern regarding the societal impact of the research topic, which was codified with a total of 53 segments evenly distributed among the three subcategories derived from the analysis: educator responsibility, social responsibility, and artist responsibility. Table 7 shows the distribution of segments and references within each subcategory.

Table 7 Codified segments in each subcategory regarding societal concern on the research subject

Subcategories	Segments	Documents
Educator responsibility	24	9
Social responsibility	17	8
Artist responsibility	12	7

Source: (information omitted for reviewing procedure)

Regarding educator responsibility, the majority of participants identified the responsibility that educators hold as exemplar models for their students regarding environmental concerns: "They are like seeds that one leaves behind, both musicians and educators, and perhaps over time, some of them will sprout, leaving something behind" (E2). Participant teachers include references considering that education, including the engagement of music teachers with their environment and the active involvement of the entire school community, is crucial for fostering artist consciousness and emphasizing the role of educators as exemplary figures responsible for prioritizing activist themes, raising environmental awareness, and promoting lifelong, holistic education, all while encouraging positive perspectives on environmental issues and inspiring teachers as citizens to contribute to a better world.

Concerning social responsibility, all interviewed music educators acknowledge that, as members of our community, they collectively share a responsibility concerning environmental matters: "more so as citizens than as musicians, regardless of whether they are musicians or not." (E6). Specifically, this subcategory includes references that underscore the multi-dimensional nature of environmental responsibilities, ranging from the political sphere to individual homes, emphasizing the role of citizens and cultural influencers, including musicians, in promoting sustainability and environmental awareness.

The last subcategory analyses artists' responsibility in environmental education as a social concern, recognizing the role of musicians as influential figures. Teachers mainly acknowledge that artists play a multifaceted role in societal consciousness for promoting environmental awareness, whether through their concerns in their works, their role as exemplars, their experiences with

environmental problems, their responsibility as citizens, their lyrics advocating for social issues, their potential as public figures raising awareness, or their instruments fostering awareness. One of the interviewed teachers considers that "each step they take, even if small, is exemplary, and they indeed have to play an important role in that subject" (E2), emphasizing the role of artists in promoting positive changes.

Table 8 compiles the most significant testimonies from each of the previously explained categories.

Table 8 Teacher's testimonies for each subcategory regarding the identification of environmental themes related to music

Subcategories	Testimonies
Educator responsibility	*I am a music teacher, but I also consider myself an educator. I believe that I not only have to teach music but also teach music and connect it with the environment that surrounds me (...) There are so many things I am responsible for when I choose the music we play, interpret, and work on, the way I address them. For me, all these values have to be present. And of course, for me, environmental issues are also a topic that carries weight, not only in my subject but in any subject* (E2). *We mustn't forget that a teacher is a figure who should set an example. So we* (the teachers)*, more than anyone, are the ones who have to instill in them* (the students) *a respect for the environment and environmental awareness* (E7). *We* (the teachers) *have to educate. What remains as a legacy? Well, if it remains in just a few, and those few transmit it to others, then maybe we can create responsible adults* (E10).
Social responsibility	*Music has a social impact. It creates trends, styles, ways of living, raises awareness, shapes personality. It must be, of course, music created with quality and that is close to the audience, music that people enjoy, and it shouldn't come across as a slogan, something forced; it should be clear that something is being instilled with intent* (E1). *Yes, I believe that all of us, regardless of who we are, should accept our responsibilities and obligations towards the environment* (E6). *We all have a responsibility, whether as a society, as teachers, or as citizens living in this world, right?* (E9).
Artist responsibility	*If something is truly a concern for the artist, it's much easier for something truly meaningful to emerge, something that conveys* (E1). *The lyrics of music can provide us with a lot of material to be very outspoken and to assert and argue many things that we may not have so clear* (E7). *As a musician, in my case because I'm not a very public figure, but certainly from the perspective of a public figure or a famous musician, with all their actions, they can promote that awareness because they have the means to bring a problem or a need to visibility* (E7).

Source: (information omitted for reviewing procedure)

The qualitative analysis regarding teachers' knowledge and perceptions addressed in this section underscores the multifaceted role of music within the

context of environmental education, shedding light on its potential as a powerful educational tool for fostering environmental awareness and engagement, highlighting the role of music teachers as figures with social, educational and artist responsibilities. The following section enables a comprehensive view of the researched theme, presenting a combined interpretation of quantitative and qualitative data through the triangulation process.

5 Discussion: Triangulating Quantitative and Qualitative findings

To enhance the validity and reliability of research findings, methodological triangulation is addressed in this chapter to compare results from quantitative and qualitative data sources to validate and corroborate the main research findings. This approach is particularly valuable in mixed-methods research, by providing a more complete picture of the phenomenon under investigation (Denzin, 1970), considering the strengths and limitations of each data type, and drawing meaningful conclusions that address the research dimensions.

The initial dimension under consideration pertains to teachers' knowledge in the environmental field and training in the use of music as a didactic resource for environmental education. A quantitative examination of the data reveals several noteworthy findings. First, a substantial percentage (70%) of the participant teachers claim to possess some degree of prior knowledge regarding environmental education. In contrast, a smaller percentage (50%) acknowledge possessing prior knowledge concerning the potential uses of music for environmental awareness. Notably, the majority of educators (91.1%) have never undergone interdisciplinary training that bridges both of these subject areas.

To gain a deeper insight into these findings, the qualitative analysis brings to light the specific viewpoints held by music educators regarding the concept of environmental education. Interviews revealed that teachers predominantly view this subject from a pedagogical standpoint, emphasizing in its significance as a cross-curricular content and advocating for its inclusion in the curriculum of all subjects, including music. Additionally, educators highlight perspectives focused on developing sensitivity towards the natural environment, connecting with emotional and personal values, and considering social responsibilities when conserving, understanding, perceiving and respecting the environment. These diverse approaches reveal a multi-dimensional conception of environmental education, connecting with culture and society (Sauvé, 2014) in contrast to reductionist perspectives that confine the field solely to a naturalistic approach (Gaudiano González & Meira Cartea, 2009).

When analyzing specific knowledge in connecting music and ecology, both quantitative and qualitative findings provide important findings. Notably, according to the quantitative data obtained, a significant portion of the participant teachers (69.3%) acknowledge the connections between music and ecological content. The statistical analysis of correlations reveals a direct relationship between having prior knowledge in environmental education and possessing prior knowledge in using music as a means of promoting environmental awareness, revealing that music educators with a background in environmental issues also receive training on how to incorporate these topics into their curriculum. Regarding specific thematical, the subjects that explore the intersections of music and evolution, as well as those delving into the biological aspects of music, are the most recognized. Conversely, the areas about music in the animal kingdom and

the application of ecology to music are less well-known by participant teachers. Additionally, the qualitative analysis also highlights many of these themes and introduces others that are not mentioned in the questionnaires, highlighting topics related to acoustic ecology, the negative effects of noise pollution, the biological origin of materials used in instrument construction, the connections of music with the brain and the body, to traditional music as cultural heritage intertwined with the environment, to the emotional functions of music, to the sounds of living beings and their ecosystems, as well as to philosophical conceptions of music and its relationship with other disciplines such as mathematics or physics.

In addition to assessing educators' prior knowledge and conceptual understanding of environmental education and music, this dimension explores the pedagogical experiences that have contributed to their expertise in these domains. Regarding quantitative findings, formal education (69.3%), versus non-formal (42%) and formal (32%) institutional education, has emerged as the predominant source of professional development in these areas. However, results also suggest that the knowledge about concrete educational initiatives addressing ecological issues through music remains notably scarce (17.82%). Moreover, the overall level of preparedness among educators across diverse disciplines regarding this subject fails to attain substantial levels (always under 40%). It is noteworthy that teachers specializing in the field of natural sciences receive the highest ratings in terms of their competencies, and this distinction is also observed between primary and secondary school levels. This perception contrasts with the fact that educators participating in the empirical research emphasize the students' receptiveness to the utilization of music as an instructional resource in environmental education. These results align with the perspective of Ballard & Pandya (2003), who consider that despite environmental education being inherently interdisciplinary, educational programs typically do not incorporate this approach.

Consistently, qualitative data highlights that the interviewed teachers express a need for training in utilizing music as an instructional tool for environmental consciousness, advocating for improved specific training in ecological matters and the creation of sustainable projects to ensure continuity within educational initiatives. A significant portion of the teaching participants incorporate environmental themes within their music classrooms driven by their convictions, actions and values, reaffirming the significance of the emotional dimension in environmental education emphasized by Selhub & Logan (2013) and the need to foster a personal connection with environmental issues to instigate behavioral changes in the educational community.

The second dimension under study addresses the perception of music teachers about an interdisciplinary approach to the environmental field. Both quantitative and qualitative findings reveal the significant societal impact of the chosen research theme. An overwhelming majority of educators (93.93%) hold positive views on the social implications of this topic, and a substantial portion (83.2%) demonstrates a genuine concern for promoting environmental awareness within their subject. Additionally, nearly half of the participant teachers (49.5%) express a keen interest in integrating environmental content into music education, and only a negligible group (3%) appears to show minimal or no interest. In fact, the correlation analysis within this dimension reveals a significant association between the perception of the social influence of the research theme and these two variables, showing that those educators who recognize a social impact related to the research theme are also the ones who demonstrate a heightened

environmental awareness and a stronger interest in incorporating this theme into their music teaching.

To delve further into the social impact of the subject matter, qualitative analysis provides insights into how music educators perceive their responsibility concerning ecological issues, considering their roles as educators, members of society, and artists. Regarding their educator responsibility, a substantial portion of the surveyed educators believe that music teachers bear a significant responsibility in environmental commitment, embracing their exemplary role for students, particularly when making choices about the themes and songs incorporated into the classroom. Similarly, Bachiorri's (2018) research emphasizes the role of educators in imparting values and behaviors, fostering creativity as active citizens, and nurturing competencies to promote social initiatives. Regarding social responsibility, teachers identify themselves as members of the community carrying a broader responsibility to instill awareness about environmental issues and to convey a constructive outlook that encourages creative solutions. In this sense, they consider music plays a pivotal role in shaping trends, styles, and societal norms, and as such, they should orient their influence toward promoting sustainable lifestyles. Finally, considering their artist responsibilities as public figures, interviewed teachers point out their responsibility in shedding light on and drawing attention to social issues, especially in the lyrics of their songs and the choice of their musical instruments for raising awareness. These findings underscore the significance of the social activism approach of this research, revealing that arts must engage with and critique reality, serving as an instrument for social advocacy (Denzin & Lincoln, 1998) and being connected with the environment (Dewey, 1938).

The outcomes within this dimension also investigate teachers' eagerness to incorporate environmental awareness initiatives into their classrooms, revealing that the majority of the surveyed population (87.1%) deems it essential to introduce musical activities for environmental awareness such as promoting ecological values, exploring the sounds of the natural world, crafting instruments from recycled materials, addressing noise pollution issues, organizing festivals and concerts in natural settings, analyzing music that pertains to environmental themes, and other activities such as scientific experiments, didactic concerts and storytelling. Interestingly, the same correlation pattern emerges when considering this variable in relation to the aforementioned variables: the educators' environmental concern and their interest in the didactic application of the theme. This highlights that educators who express a more favorable perspective regarding the practical integration of the theme are also the ones demonstrating increased environmental awareness and a stronger dedication to incorporating this theme into their teaching practices.

To enhance the rigor and credibility of the research findings, the last variable within Dimension 2 assesses teachers' overall evaluation of the pedagogical potential of an interdisciplinary approach to music and ecology. Quantitative findings reveal that teachers maintain a positive viewpoint regarding the efficacy of the research subject, as a significant majority of the participant educators consider the use of music as a pedagogical means for promoting environmental awareness in a very positive (27.7%) or positive (42.6%) way, and only a small fraction of respondents (6%) holds unfavorable assessments. In order to delve deeper into the specific and most significant contributions that music can offer to environmental education from the educators' perspective, qualitative analysis

reveals its utility as a communication and sensitization resource, as a reflective tool, as a practical resource for internalizing content, and as a means of stimulating perception. In this regard, numerous authors (Sanfeliu, 2010; Coutinho, 2014; Pedelty, 2012; Publicover et al., 2018) emphasize music's emotional, affective and communicative potential for fostering social-environmental awareness. Specifically, teachers highlight the capacity of music to engage individuals of all age groups, to instill pro-environmental behaviors, to foster social critique and formulate social slogans, to impart values and cultivate positive attitudes, to encourage creative solutions, to assimilate educational content and to connect with nature and the environment.

Finally, apart from providing a comprehensive view of both study dimensions, this triangulation process also allows for an examination of potential correlations between these dimensions. Specifically, the quantitative analysis reveals the existence of correlation relationships between variables in both dimensions. On one hand, musical and environmental content relationships contemplated by teachers (Dimension 1) correlate with their perception of the social impact of the theme (Dimension 2). This suggests that educators who establish stronger connections are the ones who perceive its social relevance more significantly. On the other hand, the interdisciplinary educational background between music and ecology (Dimension 1) correlates with the teacher's assessment of the theme's didactic application (Dimension 2). This implies that educators with a more comprehensive background are those holding a more positive view of the theme's application in the classroom. These relations serve to underscore the complexity of the topic under investigation, increasing the overall trustworthiness of the research outcomes.

6 Conclusions

The results of this study underscore the need to delve deeper into investigations that promote and revitalize an interdisciplinary approach bridging ecology and music. Environmental issues possess a multidimensional scope that necessitates cross-disciplinary engagement across all fields, including music. Throughout this study, we have observed how the educational relationship between science and music, which dates back to ancient Greece, has gradually eroded with the increasing specialization of knowledge and the detachment of humanity from its natural environment. Consequently, the interconnectedness between culture, society, and the environment, which Education for Sustainability now seeks to recover, has also been lost along the way. Music has progressively diminished in its role within the educational system, often being exclusively associated with entertainment, thus neglecting its considerable pedagogical, emotional, social, and communicative potential.

This research aims to revive the interdisciplinary perspective of environmental education and reclaim the educational potential of artistic subjects by examining the knowledge and perceptions of music educators regarding the integration of ecological and musical content. Nevertheless, the study's limitations have confined this analysis solely to music educators. We believe that it would be imperative to broaden this investigation by including the perspectives of science educators, especially those teaching subjects directly related to environmental sciences such as Natural Sciences in primary education or Biology in secondary education. Furthermore, expanding the research to encompass the entire country or

replicating the study in other locations would also be valuable for comparing data and deriving more insightful conclusions for addressing this theme in classrooms in the future.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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