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Educating sounds: music as a bioeducational catalyst in teaching

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Abstract: This paper aims to explore the connection between music, neuroscience and pedagogy within the theoretical framework of bioeducational sciences. Specifically, the work highlights the role of music as an educational tool capable of activating complex cognitive, affective and social processes, supporting the global development of the individual according to an embodied approach. In particular, the didactic implications of neuroscientific discoveries in relation to musical learning are taken as a reference, highlighting the centrality of motivation, corporeality and the relational dimension in educational contexts. The contribution wants, therefore, to offer a theoretical-operational reflection for an inclusive and conscious music teaching, able to enhance the transformative potential of music in educational paths.

Keywords: Keywords: music; bioeducation; didactics.

1. Introduction

In recent decades, bioeducational sciences have acquired increasing relevance within the pedagogical and neuroscientific landscape, proposing themselves as an interdisciplinary field of study aimed at investigating the interconnections between biology, education and cognitive processes (Frauenfelder, 2004). The interest in these connections' stems from the awareness that learning mechanisms cannot be fully understood without an in-depth reflection on the structure and functionality of the brain, in constant dialogue with the educational and cultural environment. In this context, music is configured not only as an artistic form and means of expression, but as a powerful pedagogical catalyst, capable of influencing brain plasticity and promoting integrated learning, involving both the cognitive and the emotional-relational spheres (Ciasullo, 2015).

The present research is part of this theoretical horizon, proposing an analysis of the role of music within the bioeducational sciences and highlighting how musical practices can support the neurocognitive, effective and social development of the individual. In particular, the focus is on the transformative value of music in educational contexts, with a focus on the educational implications deriving from the most recent neuroscientific discoveries. Through a multidisciplinary approach, the work aims to highlight the importance of inclusive music education, based on a holistic vision of learning and oriented towards the enhancement of human potential in all its forms.

[1] The paper is a scientific collaboration between the authors. However, the allocation of paragraphs is as follows: Alessio Di Paolo is the author of the entire work; Michele Domenico Todino is the scientific coordinator.

2. The importance of bioeducational sciences in teaching

Bioeducational sciences are a rapidly expanding multidisciplinary field, able to offer a deeper understanding of the connections between biology, education and learning (Carroll et al., 2017). These sciences focus on the study of neurobiological processes and the pedagogical implications of these processes, emphasizing how the structure and functionality of the brain are influenced and shaped by education. However, they owe much of their progress to the investigations carried out in the neuroscientific field, to determine in which form the brain influences educational and training processes, together with a cultural impact influencing this dialogic mechanism between *nature* and *nurture*. Within this scenario, music emerges not only as an expressive and artistic medium, but also as a powerful tool for learning and cognitive transformation (Schlaug et al., 2005), as it represents a universal language capable of strongly stimulating the brain areas involved in attention, memorization, creativity and emotionality, promoting holistic and interdisciplinary learning (Frauenfelder et al., 2013).

The bioeducational perspective, therefore, offers an essential frame of reference for understanding how music, through its rhythmic, melodic and harmonic characteristics, can influence the brain and learning processes. Recent studies show that exposure to music, especially during childhood, can promote neuroplasticity, i.e. the brain's ability to adapt and reorganize itself in response to new stimuli (Stegemöller, 2014; Zaatar et al., 2024). This phenomenon is not limited to the cognitive sphere but extends to the emotional and social dimension of learning, emphasizing the importance of an educational approach that integrates music as a central component (Harney, 2020).

An interesting aspect of bioeducational sciences is their ability to provide an evidence-based approach to teaching, which considers recent discoveries in the field of neuroscience. For example, studies conducted by Patel (2008) on the link between music and language have shown how music learning can improve language and phonological skills, thanks to synchronous stimulation of the brain areas responsible for these functions. This would suggest that music education should not be considered an ancillary or recreational activity, but an essential component for the integral development of learners.

In addition, neuroscientific research in the bioeducational field highlights the importance of music as a tool for inclusion and overcoming cognitive and social barriers (Burland, 2020). Musical learning, in fact, can represent an opportunity for pupils with Special Educational Needs, contributing to the enhancement of their self-esteem, as well as intervening directly in motor skills and social interaction skills (Ciasullo, 2017). In this sense, the bioeducational approach stands as an interesting resource for teachers and educators, offering innovative teaching strategies based on the understanding of neurophysiological processes and emotional dynamics that influence learning.

In order to understand the potential that, in recent years, bioeducational sciences have had in an attempt to analyze more deeply the individual-child with whom we work, it is interesting to conduct an upstream reflection, aimed at the study of neuroscience, the predominant field of investigation and which has always focused on the development of children, with a particular focus on the neurocognitive mechanisms underlying the teaching-learning process.

If we want to try to provide a definition of neuroscience, it is possible to highlight that it is configured as the set of research directions that have as their object the study of the nervous system from a normal and pathological point of view, and tend to

integrate the basic disciplines (*anatomy, biochemistry, physiology, psychology*) with neuropathology and clinical neurology; in the specific sense, prevalent in scientific and educational organizations, a group of basic research programs, which focus on the structures and functions of the nervous system, such as *neuroanatomy, neurochemistry*, *neurophysiology*, *neuropsychology*, *neurogenetics*, *neurobiophysics*, behavioral sciences and research programs on the *neuro-communication*[2].

Neuroscience, therefore, is characterized as a multidisciplinary dialogical field, having as its central object of study the brain and, more generally, the nervous system of living beings, focused on from a pluralistic chemical, genetic and molecular point of view (Green et al., 2024). In recent decades, neuroscientific approaches have favored the development of a comparison that has redetermined the boundaries of the educational sciences. This perimeter has been explored with the help of innovative investigation techniques, such as *brain imaging*, which have allowed the direct observation of human mental activities during direct activity (Kumar et al., 2022).

Modern brain imaging techniques have allowed an increasingly detailed and precise investigation of the functioning of the brain, making it possible to observe in real time the brain activity in the act of forming thoughts, articulating words, planning gestures or experiencing forms of emotions. These advanced tools have therefore offered the possibility of exploring cognitive and neurophysiological processes with a level of depth that until recently was only superficial, having significant repercussions also in the field of educational sciences.

In this context, teaching has taken on an epistemological attitude capable of combining flexibility and rigor, critically and constructively confronting the results of neuroscientific research (Gkintoni et al., 2022; Daugirdiene et al., 2024). The discoveries deriving from neuroscience have in fact raised important questions about the congruence and effectiveness of traditional educational paradigms, stimulating a reflective examination of how teaching methods can evolve in the light of new evidence. This process has led to a growing openness towards educational approaches that are based on a solid understanding of the brain mechanisms involved in learning; in particular, music education, within the bioeducational sciences, has found its relevant application, since its practices prove to be able to stimulate and model brain plasticity, promoting not only cognitive learning, but also the emotional and social development of individuals (Thomas, 2012).

The intersection between neuroscience and education is realized in the study concerning the plastic structure of the brain, capable of adapting and modifying itself in response to the stimuli received, with relevance for direct and experiential experiences and in which music can play a central role (Habib & Besson, 2009). These experiences are configured as privileged opportunities to stimulate neuronal connections, facilitating learning in a holistic way, capable of involving not only the intellectual sphere, but also the affective and motor sphere. In this context, it is interesting to highlight the possible use of bioeducational sciences as keys to decipher, face and overcome educational complexities.

[2] https://www.treccani.it/enciclopedia/neuroscienze_(Enciclopedia-Italiana)/ (last consultation date 01/04/2025)

2. Bioeducation as a key to deciphering, coping with and overcoming the complexities of learners

Following the path traced by the bioeducational sciences leads to a clear reflection on how teaching action, to be truly effective, must be translated into professionally adequate practices (Ching et al., 2020). This implies the development of strategies capable of supporting a process of knowledge construction that integrates all dimensions of the individual — cognitive, emotional, social and biological — in a constant and dynamic relationship with the context. This systemic interaction (Sibilio, 2020) is part of a complexity that is difficult to decipher, but essential for fully understanding learning processes. Bioeducational research in Italy, since its inception, has embraced and promoted this approach, acting as a meeting point between apparently opposing scientific traditions and contributing to a complete vision of education (Frauenfelder & Santoianni, 2002).

In particular, the neuroscientific exploration of brain plasticity has opened new perspectives on the role that environmental stimulus plays in the development and reorganization of neural connections, especially in the first years of life. As pointed out by Kandel & Schwartz (1982), the brain, at birth, represents the least differentiated organ of the human body. Initial synaptic connections are formed through cellular recognition processes but are still susceptible to profound transformations. This ability to adapt, known as *plasticity*, allows the brain to respond dynamically to environmental experiences, favoring the creation and elimination of synaptic connections according to their usefulness and frequency of use.

The phenomenon of *synaptic sprouting*, i.e. the "budding" of new neural connections, is particularly evident in the first years of life and represents a central process for cognitive development. During this phase, perceptual, emotional and social experiences help to select the most efficient neural networks, giving rise to a sort of *Darwinian competition* between nerve fibers. The most suitable connections to respond to environmental stimuli are those that survive and consolidate, favoring the formation of specific functional brain areas (Frauenfelder, 2001).

In this context, education plays a decisive role, since it is in educational contexts and training relationships that the mind activates its learning potential using dedicated neural networks (Tang et al., 2016). The brain's ability to adapt and reorganize itself is not a linear or automatic process, but requires intentional action that favors meaningful experiences, capable of stimulating the biochemical and structural plasticity of nervous tissue. As highlighted by Edelman (1993), during development there is an increasing variability of synapses, accompanied by the diversification of neurotransmitters and which give rise to the *humus* on which experiences select the most effective neural networks to respond to environmental inputs.

The interaction between neuroscience and bioeducation thus highlights the importance of a pedagogical approach that considers the brain not only as a plastic organ, but also as a system deeply interconnected with the environment and social relationships (Hari & Kujala, 2009). This approach not only enriches the understanding of learning processes but also offers an operational model for designing educational interventions that integrate neuroscience outcomes with educational practice. Music, in this framework, is configured as a privileged tool to stimulate and model these processes, acting as a mediator between the biological and cultural dimensions and enhancing the brain's ability *to adapt*, *learn* and *transform* itself (Ciasullo, 2015).

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Bioeducational sciences and neurosciences find a further point of convergence in the Theory of Neural Group Selection (TSGN), proposed by Edelman. This theory, based on the concept of neural Darwinism, provides an interpretative framework for understanding brain development and the processes underlying cognitive faculties. Edelman (1993) describes the human brain as a system initially characterized by a surplus of neurons that, through a process like natural selection, eliminates the less used connections and strengthens the more functional ones. It is significant to note that the unit of selection is not the single neuron, but the groups of neurons, which dynamically organize themselves in response to the interaction between the organism and the surrounding environment. This process, in which adaptive activity plays a predominant role, represents the biological foundation of learning and adaptation.

As noted by Kandel & Schwartz (1982), the brain is a highly plastic organ, in which synaptic connections, rather than the neurons themselves, undergo changes in response to experiences. Learning, therefore, does not alter the structure of neurons, but strengthens existing synapses or creates new ones through constant interaction with the context. This adaptive capacity is made possible by synaptic plasticity, which is one of the fundamental mechanisms underlying learning. In support of this perspective, Donald Hebb has proposed the *theory of discharge and connecting*, emphasizing how the simultaneous activation of weak and strong inputs to a neuronal cell can lead to the strengthening of weaker connections, a phenomenon that has profound implications for the design of educational environments (Hebb, 2005).

The application of this knowledge to the educational field requires a rethinking of teaching strategies (Sibilio, 2021). It is essential to identify strong and emotionally significant stimuli, capable of driving the weaker ones, and to create learning environments rich in stimuli, which encourage the active participation of students. Furthermore, it is essential to recognize the central role of the body in learning processes, not only as a tool of expression, but as a *medium* through which the construction and transfer of knowledge can take place. The body, in this sense, becomes an *intelligent agent* (Sibilio, 2002), a propeller of new learning and a privileged channel for the development of skills, autonomy and emotional expression.

Boncinelli (2008) has further contributed to this debate, highlighting the enormous complexity of the human brain, characterized by a million billion synaptic connections. Every lived experience, every interaction, leaves a trace in the dynamic architecture of the synapses, continuously changing the cognitive and affective landscape of the individual. This process of constant transformation underlines the importance of rich and meaningful educational environments, capable of stimulating the development of neural networks and fostering learning that integrates cognitive, emotional and bodily dimensions. Music is configured as an educational medium capable of enhancing biological and educational processes, following a bioeducational trajectory.

3. Music and bioeducation: possible intertwining

Considering musical practice in a bioeducational key implies starting from the assumption that harmony, understood as a concept aimed at structuring coexistences and regulated coexistences, offers the possibility of considering, researching and composing the reasons for a necessary complementarity between the musical and educational fields (Peretz et al., 2013). Music, in fact, turns out to be an organization governed by precise systemic rules, capable of taking on varied connotations based on

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the contexts of reference and the cultural influences deriving from these connotations. Music, therefore, can be understood as a *non-linear* process in which the experiential, mediated by the senses and, in particular, by sound stimuli, finds a specific evolutionary form in the listener's ability to rework. In fact, listening[3] to music implies a different way of interpreting what has been perceived according to the individual, and this depends largely on the cultural, ecological and intrinsic influences in the listening process itself. Already in this it is possible to see an interesting point of contact between the study of sound and the bioeducational sciences, particularly the field of biosemiotics, which tries to intertwine the perceptual investigation with the ethological one. The human being, in fact, is seen as a system capable of making precise connections with the external environment, which also become able to alter the perceptual structures responsible for the attribution of precise semiotic values and meanings to what he has heard (Ingold, trans. 2014), while at the same time realizing a possible nature-culture interconnection, enhanced through an osmotic passage of meaning between the internal sound, therefore perceived, is the external environment, thanks to which one becomes able to attribute very precise meanings. Yet, sound would not seem to be an element anchored to a precise cultural label, precisely because of its ability to adapt to different environments and different spaces, becoming a factor that can be isolated both spatially and temporally, therefore from a historical-cultural point of view, by virtue of its structural immutability. Sound, in all its possible forms, from listening, to speech, to composition, becomes an epigenetic ontological object, in which it is necessary to understand in what dimension the environment affects the ability to give meaning to what has been heard, and how listening, bound to a precise cultural context, can affect a different interpretative constituent, changeable due to the intrinsic contextual mutability. Therefore, it is possible to say that the sound environment is not only given by the external form but involves the physical energy implicit in the sound that penetrates the human fabric and allows us to reach higher cognitive levels, capable of returning the results of the mental dimension in material form (Leman, 2008). Music is configured, at the same time, as construction and principle, culture and nature, individual and environment (Ciasullo, 2015, p. 45). Describing the musical process, therefore, requires a cognitive-emotional reading, capable of predicting the musical phenomenon in everyone as a different semantic dimension, although governed by a shared syntax. Listening, for example, is an idiosyncratic phenomenon, capable of taking on different interpretative forms due to the multiple and

[3] It is necessary, however, to make a distinction between listening and feeling. "Feel" and "listen". "To hear" (from the Latin sĕntire) refers to the physical perception of sound through the ear. It is an automatic sensory process that takes place even without conscious effort. For example, you can hear the sound of a siren or the rustle of the wind without necessarily paying much attention to it.
"Listening" (from the Latin auscŭltare), on the other hand, goes beyond the simple act of perceiving sound. It implies active and conscious involvement. When you hear something, you are intentionally devoting your attention to what you are hearing. Listening usually involves a deeper understanding of sound, which may include interpreting meaning, evaluating quality, or analyzing sound structure (Riva, 2004). Listening is always selective, intentional and requires reciprocity so that it can lead to dialogue.
In short, "hearing" is an automatic process of perceiving sound, while "listening" is a conscious act that involves attention and reflection. While we can hear many sounds in our environment without thinking about it, listening requires more focused and active effort (Sweetow and Sabes, 2007).

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different sources of receptivity (Bamberg, 20005) and which, however, requires precise genetic predispositions and targeted learning strategies (d'Alonzo, 2020), as well as precise methods of analysis about the contextual exchange between the individual and the sound environment, as external stimuli produce non-univocal and unpredictable responses, the result of precise mental processes of mediation. It is necessary to resort to the cultural perspective of Vygotskian matrix, deriving from the strong additive connotation of the perceptive action of the individual and the stimulating external musical environment, which operates through instruments and signs capable of favoring a non-immediate response to the auditory process, however constantly mediated, therefore able to reduce the biological bearing in favor of a greater cultural construction, passing in this case through the form of musical mediation. Sound becomes able to harmonize the apparent dichotomous process between perception and cognition in which the *low levels* of processing and organization of responses, therefore passing through the perceptual channel alone, and the high levels of cognitive processing, capable of attributing meaning to what has been heard, due to a strong cultural influence, are alternated. Reybrouk (2008), in this regard, introduces the concept of *musical Deixis,* in which the utterance takes on a diversified and varied connotation according to the precise space-time of fruition and in relation to the people who interact in that same space-time in a given biocultural *Umwelt*. In music, the process is amplified, as there are multiple space-time coordinates within which musical enjoyment takes place. The listener, in fact, who places himself in a position to listen, accesses a determined and sequential flow of information that returns in cognitive processing certain needs, peculiarities, internal rules and that for the same are configured as a right and exact form from an interpretative point of view, according to his own context of reference, therefore relying on precise cultural axes that are intertwined with the perceptual dimension, equal in elaborative forms in all individuals (Fritz et al., 2009). Music, with its evolutionary roots and its intrinsically cultural nature, therefore, represents a fundamental element for understanding the dynamics of human learning from a bioeducational perspective. The bioeducational sciences, as already highlighted on several occasions, emerging from the intertwining of biology, pedagogy and neuroscience, offer an interpretative key to explore how musical experience can shape cognitive, emotional and social processes, as well as promote the development of transversal skills. Through the prism of bioeducation, music is conceived as an interaction between innate biological factors and environmental stimuli, in which the universal musical potential of everyone can be evolved through education and practice (Jenkins, 2011). This approach not only challenges the traditional concept of musical *talent* but reconfigures it in the light of scientific evidence that highlights the importance of sociocultural context and intentional training. This perspective finds clear articulation in the pioneering studies of Sloboda (2001), who, at the end of the twentieth century, redefined the concept of musical ability, denying the existence of an innate musical talent and supporting a universalist vision of musical ability.

The scholar, in fact, has conducted a series of studies that have revolutionized the understanding of the development of musical skills, laying solid foundations for a radical critique of the traditional concept of talent, identifying five criteria necessary to consider talent as a distinctive characteristic: it should be *genetically determined* and at least partly innate; *manifest early*; to act as a *reliable predictor of future success; characterize a minority of individuals*; and be *domain-specific*, such as music (Manturzewska, 1990; Sosniak, 1990; Davidson, 1993).

The scientific evidence collected suggests that environmental factors, such as constant practice and support from parents, teachers and peers, play an important role in the development of musical skills. Even learners who are considered talented need extensive training to achieve exceptional levels of performance. In this perspective, musical talent cannot be reduced to an innate and immutable characteristic, but emerges as a complex construct, influenced by the interaction between biological predispositions, formative experiences and social dynamics.

Howe (1998) acknowledges that some individual differences in musical ability may have a genetic origin but points out that such differences are marginal compared to the influence of educational context and opportunities. This view is further supported by the studies of Welch (2001), McPherson & Williamon (2006), who affirm that musical ability is universal and accessible to all children, if they receive adequate and continuous training.

A particularly interesting aspect concerns the perception that children themselves have of their own musical potential. Lamont & Maton (2007) show that many school-age children believe that they can achieve success in music through commitment and practice, recognizing the crucial role of motivation and hard work in the development of musical skills. This belief reflects an egalitarian approach to music, in which success is not the prerogative of a select few, but the result of an inclusive and well-structured educational process.

This conception of music as a universal ability fits perfectly into the paradigm of bioeducational sciences, which emphasize precisely the importance of the interaction between biological, cultural and social factors in human development. In a bioeducational context, music is not only a field of learning, but a means through which it is possible to promote cognitive plasticity, empathy and social cooperation, while stimulating precise brain areas involved in memory, attention and emotional regulation and creating a fertile ground for the development of transversal skills essential in contemporary society.

Furthermore, the concept of musical educability, which emerges from the studies of Sloboda (2009), aligns with the bioeducational idea that everyone possesses an intrinsic potential to be cultivated through education. This implies a paradigm shift in the educational approach, which moves from an elitist and selective vision to an *inclusive* and *universal* perspective. Music becomes, therefore, a privileged tool to promote equality of educational opportunities, breaking down the cultural and socio-economic barriers that often limit access to musical education.

Music, therefore, stands as one of the deepest expressions of the human condition, intersecting cultural, biological and psychological dimensions in a complex network of meanings and functions. From a bioeducational perspective, this artistic discipline is not only a means for the development of technical skills, but also a catalyst for emotional, cognitive and social growth. Music, in fact, stimulates connections between cerebral hemispheres, promotes neuronal plasticity and strengthens social bonds, representing an ideal bridge between educational sciences and neuroscience. It is in this context that motivation emerges as the fulcrum around which the continuity of musical learning revolves, both in childhood and adulthood. Following this perspective, it is possible to connect the topic of musical talent and development with a more in-depth analysis of motivation, which proves to be decisive for maintaining and progressing in musical skills (Cuadrado, 2019). The continuity between the two conceptual blocks underlines how the recognition of universal musical potential is

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inseparable from the understanding of the motivational forces that drive commitment over time.

The large body of research (Campbell et al., 1995; Southgate & Roscigno, 2009; Hogenes et al., 2014; Adachi, 2001) on musical practice during early childhood, converges in highlighting the importance of motivation as a protective and propulsive factor. Motivation, in fact, not only supports success but also promotes constant involvement, acting as a link between the initiation into the musical path and its continuation throughout life.

It is also interesting to highlight the potential of music to promote motivational processes. Insights into the critical role of motivation emerged as early as the 1990s, with studies such as Sloboda's, which highlighted the contribution of individual characteristics such as autonomy, resilience, achievement goals, and conceptions of abilities. Austin, Renwick & McPherson (2015) have emphasized that at the base of these characteristics there is always a robust motivation, capable of explaining why some children and young people continue to be involved in the musical environment while others move away. The initial phase of the musical journey, usually dominated by an extrinsic motivation – fueled by the support of others, external recognition and the desire to please – progressively evolves towards an intrinsic motivation, characterized by the intrinsic pleasure of the activity and the ability to self-regulate.

Extrinsic motivation is particularly significant in the early stages of music learning, when parental and teacher support can have a major influence on children's engagement. McPherson (trans. 2022) highlights how parents play a key role in fostering practice and cultivating a sense of commitment in their children, while Hallam et al. (2021) show how initial levels of motivation can predict continuous participation, thus supporting a thesis that learning is not the result of subjective biological nature alone, but of social and cultural intervention.

In relation to this idea, it is good to emphasize the transformative value of music, understood as *a language* and reflected the meaning of music, as able to transcend linguistic and cultural barriers, offering a means of communication that is rooted in human biology. Studies such as those of Bencivelli (2012) and Mithen (2006) suggest that the human ability to communicate through music may have played a fundamental role in the evolution of cognitive and social abilities. Bioeducation, in this sense, recognizes music not only as a cultural phenomenon, but as an innate and deeply rooted characteristic in our biology (Proverb, 2019).

Music, as a universal language and a tool for connecting emotion and cognition, offers a privileged look at the complexity of the human mind. In this regard, it is interesting to verify the double connotation of music both as *an expressive language* and as a *means* capable of favoring the development of spoken language. As an expressive language, it possesses specific semantic labels recognizable to each and every one, therefore able to favor an inclusive learning and communicative phenomenon, as well as diversified on the basis of the specific development of the species (Frauenfelder, 1983), as the observation is that as soon as a precise system of symbolic communication between groups is established, it is possible to use it to gain an advantage in relationships and relationships with other species. On the other hand, however, music has structural elements capable of favoring the development of the language itself, as there are specific similarities between the two dimensions. All the aspects used for the understanding of the prosody of language (intonation, emission variations, pauses, etc.), would find interesting points of connection with the musical symbolic language.

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Quite a few studies show how, from a cultural as well as neurobiological point of view, music and reading have elements of strong interconnection (Hodges, 2011). This is because, from a cognitive point of view, the brain would possess musical peculiarities that would change from other fundamental faculties to exercise this apparently accessory possibility, in which education plays a fundamental role in the potential activity of a mnestic and natural linguistic nature (Bergman et al., 2014). This happens thanks to the contribution deriving from strict musical activities. It is no coincidence that the enhancement of language activities can be a direct derivation of the enhancement of musical skills. Miller (2014) himself, although he did not possess a large vocabulary from a lexical point of view, was able to remember several pieces by heart and to communicate through a plurality of interconnections of notes, thanks to the reinforcement of the brain areas in charge.

The pedagogical field, with its transformative vocation, is called to consider more and more carefully the elements that contribute to the definition of the present. This requires not only the analysis of the data and tools that characterize contemporaneity, but also the use of diversified mediators, including music and all the possible declinations of sound related to it. The word alone is no longer sufficient to structure man's relationship with the world, while maintaining a common constitutive root with musical structuring (Levitin, 2006).

In this scenario, teaching, as an acting corpus of pedagogy, calls us to reflect on the social and transformative function of listening to music. This, repeated in specific cultural contexts, can give rise to diversified formative interpretations, educating them to critical listening and suggesting new educational hypotheses that use the musical experience as a vehicle and tool (Green et al., 2024). Music becomes the object of study in the educational and biological sciences, revealing its potential as an interpretative key to interpreting the interactions between society and education. Thus, the musical phenomenon can be analyzed through sociological, biological, cultural, anthropological and psychological lenses, providing a multidisciplinary perspective that enhances the dialogue between different approaches (Cook et al., 2013). Music, understood as a social construct, acquires its own specific form of interpretation that integrates with the social context of reference, contributing to the shared construction of knowledge.

Music is not just a language, but rather a set of languages, an expression of a plurality of communicative models that reflect the social transformations of contemporaneity and the characteristics of the new generations. This approach leads us to consider music not as an alternative language, but as a meta-language, representative and complementary to verbal language, capable of acting as an expressive and cultural bridge (Blacking, 1973).

Cognitive sciences, considered synthetic disciplines, have opened new perspectives to analyze the phenomenon. They have offered tools to understand the intertwining of nature and culture, adapting to the contexts, circumstances and relational dynamics that emerge in contemporary society (Levitin, 2006).

The perceptual act is also mediated in the musical field by the significant and evocative relationship with which it is realized and thanks to those who mediate in this cognitive process. Conceptual or categorical representations, on the other hand, refer to true arbitrary creations generated by the brain based on perceptual similarities. The perspectives are those related to the multiple intelligences of Gardner (trans. 2010), who considers music as an emanation of a distinct intelligence. Among the nine

faculties, this can be associated with linguistic intelligence, although intelligences are forms of expression autonomous from each other. It turns out that there would be, from a cerebral point of view, a specific area dedicated to music. This area would be located within a dense synaptic network of neuronal junctions, in all those people stimulated environmentally by an education or stimulation of a strong musical nature. Music, therefore, would also be configured as an exercise of human intelligence, therefore as an overall reflection of the functioning of the human brain. This would be part of a holistic discourse of brain functioning functional to the adaptive system, no less than to other cognitive activities that involve the brain itself, including creativity.

The biocultural perspective therefore provides an interpretative key to understanding how the integration of technologies and music, moreover, can promote new ways of learning that respect biological individuality and, at the same time, enhance cultural collectivity. This thought invites us to reflect on how educational technologies can not only support musical learning but also transform it into an experience deeply rooted in contemporary biocultural dynamics.

5. Conclusions

In the light of the reflections presented, it is evident that bioeducational sciences offer a valuable interpretative framework for understanding the complexity of learning processes, paying particular attention to the interaction between biological, cultural and emotional dimensions. In this scenario, music emerges as a privileged pedagogical device, capable of stimulating brain plasticity, fostering integration between multiple intelligences and promoting authentically inclusive learning.

Theoretical recognition and comparison with the most recent neuroscientific contributions have shown how musical experience, far from being an accessory activity, constitutes a powerful mediator between body, mind and environment (Gomez-Paloma et al., 2016), capable of enhancing cognitive, affective and relational skills. In particular, the analysis of motivation as a key factor in the continuity of the musical training path suggests the need to design stimulating and meaningful learning environments, capable of supporting the commitment and active participation of students.

Finally, reconsidering music as a universal language and as a form of expression deeply rooted in human biology implies a rethinking of educational practices, in the direction of a didactic that is more attentive to subjectivity, corporeality and the experiential dimension of learning. Only in this way will it be possible to build truly transformative training paths, in which everyone can cultivate and fully develop his or her potential.

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