Biosongs: enhancing cognition and emotional development through an active teaching-learning method in biosciences

Biosongs: melhorando a cognição e o desenvolvimento emocional através de um método ativo de ensino-aprendizagem em biociências

Biosongs: potenciando la cognición y el desarrollo emocional a través de un método activo de enseñanza-aprendizaje en biociencias

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ABSTRACT
Cultivating an innovative approach to education, the use of music as a teaching-learning method in Biosciences allows the enrichment of traditional pedagogy and nurtures students’ cognitive and emotional development through creative expression and interdisciplinary exploration. By developing original songs inspired in bioscience topics, we applied the concept of musical intelligence developed by Howard Gardner as a teaching-learning method in science classes for the last years of an elementary school in Rio de Janeiro (Brazil). In terms of cognition development, it is known that music promotes brain plasticity and stimulates interactions between various parts of the brain. Together with the students, we developed and worked new songs about the most
important themes in biosciences for the 7th, 8th and 9th years of elementary school. Aiming to (i) motivate the students, (ii) facilitate content memorization, (iii) increase concentration, (iv) promote affectivity, and (v) stimulate group working, we developed eight new songs based in the content of basic bioscience course. Those songs were repeatedly sung together with groups of students and overall evaluation identified an improvement of the five aspects evaluated. Providing active teaching-learning methods in science classes that place students as the center of the educational process can build a more playful, joyful, motivating, and welcoming environment for education in Brazil and worldwide. Running Title: Music stimulates the interest of children in biosciences

**Keywords:** intelligence, music, song writing, active teaching-learning methods, interdisciplinary education.

**RESUMO**

Cultivando uma abordagem inovadora à educação, o uso da música como método de ensino-aprendizagem em Biociências permite o enriquecimento da pedagogia tradicional e nutre o desenvolvimento cognitivo e emocional dos alunos através da expressão criativa e da exploração interdisciplinar. Ao desenvolver canções originais inspiradas em temas de biociência, aplicamos o conceito de inteligência musical desenvolvido por Howard Gardner como método de ensino-aprendizagem em aulas de ciências para os últimos anos do ensino fundamental no Rio de Janeiro (Brasil). Em termos de desenvolvimento da cognição, sabe-se que a música promove a plasticidade cerebral e estima as interações entre várias partes do cérebro. Junto com os alunos, desenvolvemos e trabalhamos novas canções sobre os temas mais importantes das biociências para o 7º, 8º e 9º anos do ensino fundamental. Com o objetivo de (i) motivar os alunos, (ii) facilitar a memorização de conteúdo, (iii) aumentar a concentração, (iv) promover a afetividade, e (v) estimular o trabalho em grupo, desenvolvemos oito novas músicas baseadas no conteúdo do curso básico de biociência. Essas músicas foram cantadas repetidamente junto com grupos de estudantes e a avaliação geral identificou uma melhoria dos cinco aspectos avaliados. Fornecer métodos ativos de ensino-aprendizagem em aulas de ciências que coloquem os alunos como o centro do processo educacional pode construir um ambiente mais lúdico, alegre, motivador e acolhedor para a educação no Brasil e no mundo. Running Title: Música estimula o interesse das crianças pelas biociências

**Palavras-chave:** inteligência, música, composição musical, métodos ativos de ensino-aprendizagem, educação interdisciplinar.

**RESUMEN**

Cultivando un enfoque innovador de la educación, el uso de la música como método de enseñanza-aprendizaje en Biociencias permite el enriquecimiento de la pedagogía tradicional y nutre el desarrollo cognitivo y emocional de los estudiantes a través de la expresión creativa y la exploración interdisciplinaria. Mediante el desarrollo de canciones originales inspiradas en temas de biociencia, aplicamos el concepto de inteligencia musical desarrollado por Howard Gardner como método de enseñanza-aprendizaje en las clases de ciencias de los últimos años de una escuela primaria en Río de Janeiro (Brasil). En términos de desarrollo cognitivo, se sabe que la música promueve la plasticidad cerebral y estimula las interacciones entre varias partes del cerebro. Junto con los estudiantes, desarrollamos y trabajamos nuevas canciones sobre los temas más importantes en las biociencias para los años 7, 8 y 9 de la escuela primaria. Con el objetivo de (i) motivar a los estudiantes, (ii) facilitar la memorización de contenidos, (iii) aumentar
la concentración, (iv) promover la afectividad y (v) estimular el trabajo en grupo, desarrollamos ocho nuevas canciones basadas en el contenido del curso básico de biociencia. Esas canciones fueron cantadas repetidamente junto con grupos de estudiantes y la evaluación general identificó una mejora de los cinco aspectos evaluados. Proporcionar métodos activos de enseñanza-aprendizaje en las clases de ciencias que coloquen a los estudiantes como el centro del proceso educativo puede construir un ambiente más lúdico, alegre, motivador y acogedor para la educación en Brasil y en todo el mundo. Título: La música estimula el interés de los niños por las biociencias

**Palabras clave:** inteligencia, música, escritura de canciones, métodos activos de enseñanza-aprendizaje, educación interdisciplinaria.

**1 INTRODUCTION**

Active teaching-learning methods are crucial for enhancing student engagement and promoting effective learning outcomes (Sabec et al., 2020; Dagostin et al., 2022). Various studies highlight the significance of active learning strategies in improving critical thinking, problem-solving skills, and student engagement (Kwon et al., 2017; Hussin et al., 2019; Marchan, 2021; Ulfa and Fatawi, 2021). In contrast to traditional teacher-centered approaches, active teaching methods, such as peer-to-peer interaction and small group activities, have been shown to foster a more dynamic and creative learning environment (Buchori et al., 2017). These methods not only encourage students to be more involved in the learning process but also contribute to increased interaction, motivation and satisfaction among both students and teachers (Alshatti, 2016; Alrahlah, 2016). The use of metacognitive regulation strategies has been identified as a best practice for transforming teaching and learning methods, emphasizing the importance of self-regulated learning in the educational process (Bakar & Ismail, 2020).

The application of modern teaching methods, such as flipped classrooms, interactive response systems, and arts/science approaches has been recognized as central to successful learning experiences (Masood et al., 2022; Wang, 2017). These innovative approaches not only facilitate teaching and learning but also contribute to improving student achievement and engagement (Masood et al., 2022). Overall, the adoption of active teaching-learning methods, including the use of music in the classrooms, plays a vital role in creating a dynamic and effective educational environment that enhances student learning and engagement.
1.1 MUSIC AND HUMAN HISTORY

The capacity for communication and socialization at sophisticated levels is one of the main characteristics that set humans apart from other animals. Since pre-history, humans have used sound in social events, working it through (i) communication codes, and (ii) chants devoted to deities. Those chants were initially performed through percussion and wind instruments created using materials from nature such as: wooden logs, leather, bones, straw, seeds, and the human voice.

In ancient Greece, a significant advancement happened with the invention of the monochord by Pythagoras. The monochord allowed a better understanding of music theory and the mathematical relationships governing musical harmony. It was a simple instrument consisting of a wooden box with a single string stretched along its length. By sliding a movable bridge along the string, different lengths of vibrating string could be produced, creating different pitches. In that single-stringed instrument (as its name suggests), the mathematical laws governing the harmonic series of sounds could be studied more precisely, determining the musical intervals that govern musical scales up to the present day.

1.2 HISTORICAL AND CURRENT APPROACHES TO UNDERSTAND HUMAN INTELLIGENCE

Regarding the theme of intelligence, one of the approaches that still greatly influences the understanding of human intelligence in western culture was derived from studies by the French psychologist Alfred Binet (1857-1911). Considering an understanding that prevailed for some time in Europe and expanded worldwide, Binet was one of the pioneers in the development of tests used to measure human intelligence (Binet and Simon, 1905). His studies ultimately produced tests that became known as IQ tests, on which the goal was to measure people’s intelligence using methods primarily based on logic and mathematics. Together with his colleague Théodore Simon, Binet published the Échelle Métrique d’Intelligence, the first intelligence test in history, aimed at assessing the intellectual development of children (Binet and Simon, 1908). Commissioned by the French government, the work aimed to develop an innovative way to identify children with learning difficulties (Mazur-Mosiewicz and Davis, 2011). Since then, many researchers succeeded and brought new focuses, refinements, and criticisms to their studies.
The study of intelligence associated with music, auditory perception, the study of rhythms, and individuals’ abilities to reproduce and remember songs for long time have been the subject of many studies and constitute an extremely vast research field (Izquierdo, 2002; Levitin, 2006). Classically, in his book entitled “Frames of Mind” (1983), the American psychologist Howard Gardner (1942-) theorized about the existence of eight specific types of intelligences observable and distinguishable, interacting harmoniously in any individual. Alongside with the classical intelligences measured by Binet, as the (i) linguistic and the (ii) logical-Mathematical, Gardner described six more intelligences that should be taken on account when evaluating the intelligence of individuals: the (iii) spatial, the (iv) bodily-kinesthetic, the (v) interpersonal, the (vi) intrapersonal, the (vii) naturalistic and, finally, our focus here, the (viii) musical intelligence. Among them, Gardner pointed out the musical intelligence as an important vector for the development of other intelligences (Gardner, 1983; 1985; 1999). Corroborating with Gardner, research has shown that music training is associated with other intellectual abilities, with varying correlations between music training and IQ based on different levels of music aptitude (Silvia et al., 2016).

In Brazil, Celso Antunes (1937-) popularized Gardner’s theories and adapted them to the reality of teaching. He discusses various ways of identifying, qualifying, harnessing, and monitoring students by recognizing their intelligences and their knowledge in the classroom (Antunes, 2009). Antunes also emphasizes the importance of utilizing music and musical intelligence as tools to enhance cognitive development skills such as self-esteem, self-confidence, motivation, social and emotional connections, and overall well-being (Ying, 2023). His approach aligns with studies that have shown a positive influence of long-term music education on cognitive abilities like introspection and planning, indicating a far transfer effect from executive sub-functions to academic performance scores (Jaschke et al., 2018). Moreover, Antunes’ work resonates with research that confirms the relationship between music and emotional intelligence, suggesting that music can be utilized as a tool to develop emotional competence in educational settings (Magraner et al., 2021). This connection between music education and emotional intelligence is further supported by studies that explore the impact of music education on mental health, with emotional intelligence playing a moderating role in how music education affects university students’ mental well-being (Wang et al., 2022). This is in consonance with our studies, on which we developed four songs together with undergraduate students of biology, and also improved initial approaches produced by the
elementary school children. The pioneering work of Celso Antunes aligns with a body of research that highlights the positive impact of music education on cognitive development, emotional intelligence, and overall well-being. By emphasizing the role of music and musical intelligence in enhancing various skills and abilities, Antunes contributes to the growing understanding of the benefits of music education in fostering holistic development in individuals.

Paulo Freire (1921-1997) also emphasizes this issue in his classic work “Pedagogy of the Oppressed” suggesting that students’ everyday experiences should be used in the construction of knowledge and participate in the formal learning process (Freire, 1968). Here, we will highlight the relevance of students’ musical studies inside and outside the classrooms. We also take inspiration from Anísio Teixeira (1900-1971), a Bahian intellectual who envisioned a public school of quality for democratizing the construction of knowledge in a country as unequal as Brazil. Every school must be open to diversity and artistic practices, constituting an incredibly strong and effective link in the humanistic and civic education of students in Brazilian public schools (Teixeira, 1953; 1969).

2 THE DEVELOPMENT OF BIOSONGS

Aiming to produce songs to inspire children and develop their musical intelligences, among other cognitive capacities, we developed songs based in the curriculum of life sciences for the students from the 7th, 8th and 9th years of elementary school. Nine topics were selected within the contents of the science course (according to the Brazilian governmental practices, BNCC; Brasil, 2018) that we considered more inspiring and relevant to compose and produce original songs. We composed eight new songs, being four created through a direct interaction with the children, and four created together with undergraduate Biology students along the course of “Workshop of Science, Arts and Education”. All songs were developed aiming to provide a playful, enjoyable time for the students, with lyrics and choruses designed to facilitate content memorization and emotionally integrate the group.

Additionally, all songs were written in musical notation to produce a Songbook entitled Biosongs, which provides a brief description of each science subject under description, as well as lyrics and musical scores with melody and harmony (Chediak, 1986). The musical scores can be used by science and music teachers in schools to guide learning in an interdisciplinary fashion, and the biosongs can be reproduced on keyboard, guitar, or any solo instrument. At this moment, we are finishing producing the Biosongs.
songbook, a PDF book presenting musical scores, containing lyrics, and chord symbols for guitar or keyboard. Also, we aim to record the biosongs by performing with experienced musicians. For each subject addressed in the songs, a brief and direct scientific information will be provided about the theme of each song and its relationship with the descriptors proposed by the Municipal Education Department of Rio de Janeiro (SME-RJ). The biosongs were thought to be based on different traditional musical genres of Brazilian culture, so that students can also learn the different rhythms, such as samba, bossa nova, forró, MPB, frevo, coco de embolada, marchinhas, etc. (Motta, 2016). The songbook will also include a brief guide providing a pedagogical proposal to be carried out by both music and science teachers, or even other elementary school subjects, aiming at composing songs with the participation of students, in order to learn, assimilate, and memorize the contents studied each semester. This way, teachers themselves will be able to reproduce our dynamics based on data they believe to be most relevant, easily rememberable, and capable of promoting happiness and affection in their group of students. The material will be made available freely on the internet.

Poetically, we could say that humans are musical by nature and live life in “verse and prose”, in a rhythmic language. Walking, heartbeat rhythms, dances, and the songs of our idols are part of our daily lives. Young students will develop their artistic-musical potential through singing and rhythmic body movement (Dalcroze, 2007), in addition to receiving the proposed information, leading them to assimilate scientific knowledge conveyed by the songs with lightness of soul and art. Interactive dynamics provided by this active teaching-learning method will reinforce group cohesion and act to bring more emotionality to studies, fostering affection among students.

It is well known that emotions and affection play a crucial role in the elementary school classroom environment, impacting students’ learning, behavior, and overall well-being. Research has shown that classrooms high in emotional support can attenuate the stability of students’ internalizing behavior, emphasizing the importance of creating a positive emotional climate (Griggs et al., 2016). Additionally, studies have highlighted the significance of another type of intelligence, the “emotional intelligence” in educational settings, with educators’ emotions affecting various aspects of their work and students’ experiences (Zhang, 2021). Thus, teachers like us, who recognize, and handle students’ emotions effectively contribute to a supportive learning environment that enhances creativity and emotional development (Siu & Wong, 2014). Moreover, emotional intelligence and affective practices are essential components of effective
teaching and learning in elementary schools. Understanding and addressing students’ emotions through sociocultural perspectives and scaffolding social and emotional learning can contribute to a more engaging and supportive classroom community (Morcom, 2014). Thus, art and music education have been recognized for its beneficial influence on students’ emotional cultivation, highlighting the importance of incorporating diverse forms of expression to enhance emotional development (Guo, 2017).

Although there are examples of song parodies used for educational purposes, our work proposed the use of original songs composed by ourselves, sometimes together with the students, for this purpose. It has not been evaluated in literature whether students can indeed better memorize the contents and relate them to other acquired contents if they listen to and memorize an “educational” song originally composed for this purpose. On the other hand, it is now clear that the affective-emotional relationship of students during the artscience dynamics could contribute to better performance in the content assessments. Research suggests that emotion plays a crucial role in educational settings, influencing job satisfaction, burnout, and overall well-being (Lee et al., 2019). Studies have shown that emotional intelligence can enhance work engagement and organizational commitment not only with the students but also among educators, leading to higher levels of dedication to their institutions (Nagalingam et al., 2019). Therefore, the use of active learning methods based on music and artscience can promote an overall reinforcement of the entire educational system.

3 THE EIGHT BIOSONGS

The biosongs described below are original and will comprise the BioSongs songbook, which will be edited and distributed as a PDF in a website along with a MP3 version of each biosong (under development). The songs will be recorded in a studio with selected soloists and students, with prior authorization from their guardians. All musical scores have already been registered at the School of Music of the Federal University of Rio de Janeiro, which is the competent authority for this purpose in the city of Rio de Janeiro. The songbook will consist of a text that briefly addresses the songs’ themes, together with the song lyrics, and musical scores for solo voice, instrumental harmony, and accompaniment with chord symbols. Additionally, each biosong will be arranged for specific musical groups and Brazilian genres, using specific instrumentation and orchestration based on field research and seeking to observe the musicology of each musical genre used. Brazilian rhythms are a diverse aspect of musicology that
encompasses a wide range of styles and influences. The music of Brazil is known for its vibrant rhythms, which reflect the country’s cultural diversity and heritage. Brazilian rhythms are rooted in African, European, and Indigenous traditions, creating a unique musical landscape. Thus, Biosongs will be both a science book to teach music and a music book to teach sciences, under a clear interdisciplinary approach.

*Biosong #1: The Five Rs* (5R’s) song alerts us to the need for good environmental practices such as Recycling, Reducing, Refusing, Reusing, and Rethinking our attitudes, contributing to nature preservation, and conserving the environment and natural resources. This music was done together with the students, that went out into the field to put these objectives into practice, an imperative action in our current society in the Anthropocene age (Steffen et al., 2011). The song was composed in the musical genre Samba-pagode, which is well known in the musical scene of Rio de Janeiro and Brazil. Figure 1 shows the musical score that will be part of the Songbook Biosongs.

*Biosong #2: The Flavivirus’* song talks about neglected tropical diseases such as Dengue, Zika, Chikungunya, and Yellow Fever. Those are tropical arthropod-borne viral diseases (arboviroses) transmitted by mosquitoes. The song suggests precautions one must take in our daily lives to prevent the proliferation of mosquitoes. Along the presentation of this song, we mixed the singing with a theatrical play in the classroom. Some students dressed up as mosquitoes performed brief scenic entries about this theme, chasing their colleagues as if they were willing to “bite and infect” them. The song was composed in the Pagode genre, which is well known and widely spread in Brazil, especially in the musical scene of Rio de Janeiro, though it has a large national reach too.
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Figure 1: The Biosongs Songbook (*book under preparation*); a) Cover of the Biosongs Songbook, b) lyrics and harmony of the song “The Five Rs”; c) part of the musical score for the same song.

Biosong #3: The song **Frevendo Ciência** leads us to think about the need of knowledge as a form of liberation and development. It praises the knowledge acquisition and talks about the relevance of schooling, book reading, inclusion, and the responsibilities of educators and learners in scientific practice. It also deals with the relationship of science and the arts, such as visual arts, theater, music, dance, and literature. The composition was produced in the Frevo musical genre, originating from the Brazilian northeast state of Pernambuco as a fervent and swift rhythm. Traditionally, performers dance in pairs with their colorful umbrellas in a beautiful party. We used percussion instruments (bass drum, surdo, and snare drum) to keep the rhythm. Frevo is a common genre in the carnival of the traditional cities of Olinda and Recife.

Biosong #4: The song **Coco Azedo Fake News** is a fun *Coco de Embolada*, a musical genre common in Northeast Brazil, especially in the state of Rio Grande do Norte. It depicts a scene representing coconut sellers singers that improvise verses or, in this case, give us warnings about the issue of fake news. Fake news refers to false or misleading information presented as legitimate news. In today’s digital age, the proliferation of fake news has become a significant concern due to its potential to deceive, manipulate public opinion, and undermine trust in credible sources of information. The spread of fake news is often facilitated by social media platforms, where misinformation can quickly reach a wide audience and be shared rapidly without proper fact-checking. The message conveyed by the music could apply to any situation and time: we should not write, forward, or send doubtful information to avoid major social disruptions. The
students performed small skits using costumes and typical musical instruments of the genre, especially tambourines. They also used broken coconut shells. This genre can also be performed by the typical northeastern trio (bass drum, triangle, and accordion). Typically, improvised verses are accompanied by tambourines by the singers, known as “repentistas”.

*Biosong #5* - The song **Ecosystems** addresses the issues of ecology, environmentalism and the protection and valorization of indigenous people. Also, it humorously explains the food chain, and talks about the Brazilian biomes and ecosystems, focusing on our responsibility of preserving Earth. It uses the expression “Pachamama”, a term that originates from Andean cultures, particularly in the indigenous Quechua and Aymara traditions of South America. It refers to the concept of Mother Earth or Mother Nature, symbolizing the interconnectedness between humans and the natural world. Pachamama embodies the idea of a living and nurturing entity that sustains all life on Earth and is revered for its sacredness and vital role in indigenous cosmology. Students, dressed like rockers with wigs had fun with Pop or Rock style in a sort of cultural fusion developed to merge different cultural elements, practices, and traditions, creating a new and unique atmosphere. A light arrangement, with keyboard, guitar, drums, and bass, was suggested to allow students to experience the feeling of a rock band, together with Indian “maracas” to provide a feeling of the traditional cultures from Americas.

*Biosong #6*: The song **Algae** shows us the importance of algae as the most significant organisms to produce the gas oxygen in the atmosphere, as it plays with the common sense that the trees from the Amazon rainforest would be the main oxygen productors. It talks about the colors and variety of algae, explaining their multiple functions within the ecosystems, mainly in the oceans. The singers, each symbolizing a type of algae, represented their role in the photosynthetic process. The composition was executed in a march rhythm using two different bass drums (bombo and surdo), and snare drum, in addition to a keyboard. This composition gave a solemn march feel to awaken us from our bad practices when, directly or indirectly, we pollute the seas and oceans. For the sake of popularization of the lyrics, we also conceived a reggae version of this song, where this contagious rhythm invites the students to dance while singing altogether.

*Biosong #7*: The song **DNA is the guy** reaffirms the importance of the genomic information and heredity for life. Genomic information and heredity play a fundamental role in shaping life and its diversity. The genetic material encoded in an organism’s DNA contains instructions for the development, functioning, inheritance of traits, and the
production of proteins and several RNA types. Genomic information is crucial for various biological processes, including growth, metabolism, reproduction, and response to the environment. The music addresses the theme in a light and simple way. This was developed in the genre “bossa nova” with its typical instruments: guitar, tambourine, and bass drum. A simple melody developed by the students was quite easy and intuitive. Students from various backgrounds gathered to sing the message proposed by the song in one voice.

**Biosong #8:** The song **Rap of education** composed by the elementary school students talks about their school life, with friends, subjects, social relationships, and the knowledge necessary for learning. Rap music, characterized by its rhythmic delivery of lyrics over a beat, has been influenced by cultural trends, linguistic styles, and musical innovations. From the early days of hip-hop to contemporary rap genres, artists have experimented with different rhythmic structures, cadences, and flows to create unique and engaging musical compositions. The current rap emphasizes the student interaction and the relationship with a school that welcomes them, providing them with knowledge and teachings for helping them in life. Set to an electronic ‘batidão’ beat, the song featured rhythmic-musical programming specifically composed for this music. The rap comes with its discourse of poetic, cheerful, mocking rhymes, but with great and vehement truths. The song was performed by a duo of student MCs (Master of Conference) who engaged and literally entered into the rap way of life.

**4 THE PARTICIPATION OF THE STUDENTS AND THEIR MULTIPLE INTELLIGENCES**

Our approach was applied to 42 students from the Elementary School (7th, 8th, and 9th grades) within the age range of 12 to 15 years, which Jean Piaget termed the formal operational stage, in which the adolescent has awareness and autonomy in perceiving facts (Piaget, 1971). The students dedicated themselves to every stage of the research in the classroom and put their skills into practice as soloists, actors, and dancers.

Here we present the illustration of two students and a testimonial (Figure 2) as a sample of many drawings they created in a creative and artistic way. The various songs, each with its themes (algae, DNA, recycling, pop, *bossa nova*, *pagode*, rap, *coco de embolada*, forró, and frevo) were represented not only in relation to their themes, but also to the Brazilian region where the musical genre was either created or developed. We also collected testimonials about the work of the students, their parents and teachers during
the test period. All of them reported that musical learning had been accompanied by improvements in behavior and socialization. We have selected one from each style to exemplify (Figure 2).

Figure 2. Drawing and testimonial from two 8th grade students: a) Juliana, and b) Julia (used with permission). In the testimonial, it reads: “Culture shown in the best way [in the class]. Well, obviously, I am talking about music. I have always loved music, all kinds of music, especially the Brazilian ones. Music, dance, and arts in general helps to control and stabilize my emotions, whether they are the liveliest or the saddest. When listening to music does not help, writing does. I write music like a diary, where everyone can read, listen, and interpret it however they want. They will never really know what I meant. By the way, I am about to release a song entitled ‘my chaos,’ along with a friend. I am excited! And I got so excited that I forgot to mention my name, my name is Julia and, with a lot of effort involved, I will be a future singer and songwriter.”

Source: the authors.

5 RESULTS

Up to this point, our research has found a fertile path to motivate and facilitate knowledge acquisition and insights by the adolescents. While challenging, as it involves our own students in an age group of constant transformations, we are certain that education associated with music can contribute significantly to shaping more affectionate and better-prepared adults for the challenges of everyday life and their professional endeavors. It is observed that in countries that invest both in science and in the arts as allies of education, students become emotionally more intelligent and capable of responding to society’s demands in a loving manner (Brescia, 2003, p. 75). Thus, the current artscience approach brings more lightness of soul and beauty, providing inspiration and, together with biosciences studies, a comprehensive humanistic formation.
During the period of implementing and applying our biosongs active method of teaching-learning, we observed two students diagnosed with attention deficit hyperactivity disorder (ADHD) and cognitive dysfunctions, who were performing below average. They were captivated by our dynamics and showed renewed commitment and joy in participating in artistic activities, exhibiting substantial improvements in socialization (Muszkat, 2000; 2011; Loureiro, 2022, p.37) and stable academic performance. ADHD is a neurodevelopmental disorder characterized by difficulties with attention, hyperactivity, and impulsivity. These students had been monitored by psychologists and used medications prescribed by doctors. Parents closely monitored their school activities and noticed an improvement in performance, attributed to the formal study of music and the choir singing of biosongs.

Also, a significant part of the students participated in the outreach project “The Incredible Science of Leopoldo de Meis” from the Institute of Medical Biochemistry Leopoldo de Meis (IBqM) at the Federal University of Rio de Janeiro (UFRJ) (Figure 3). These students participated in a large choir that sang one of the project’s songs #5 (“Ecosystems”) during a theater performance in the Quinhentão theater, at the Health Sciences Center (Centro de Ciências da Saúde, CCS) of the Fundão Campus (UFRJ). On the same occasion, two 7th grade students sang the biosong #8 “Rap da Educação”, and a solo student sang the song “DNA is the guy”, with the participation of a Chamber Orchestra (Orquestra de Câmara da Ilha do Governador, OCIG). OCIG had the participation of six project students: three on violins, two on keyboards, and one on the xylophone. In addition to the musical intelligence and their development throughout the research period, some students demonstrated the development of other intelligences, such as logical-mathematical, inter and intrapersonal, bodily-kinesthetic, and linguistic ones. Many succeeded in other areas of multiple intelligences (Gardner, 1983), achieving recognition and awards. One project student won the gold medal in the mathematics relay of the Arquimedes project at UFRJ, and another was awarded a computer in a literary essay contest.
The students also executed a presentation at the Arts, Music, and Dance exhibition of the Municipality of Rio de Janeiro, at the 11th Regional Education Coordination, where students integrated with the artistic community of the municipal network (Figure 4). They danced and sang the biosong #3 “Frevendo Ciência” as well as another rap about globalization, composed by the students. There was great interaction between the schools and socialization among the students. The performance involved the participation of the entire school community and the students’ families.

The group involved in the research has shown substantial improvement in music classes and other subjects, as more than 50% achieved averages above 85 (out of 100). They were capable to memorize both the songs and their instrumental parts, which were practiced and rehearsed in the classroom. We conducted an evaluation of the students on the themes addressed by the songs, and over 80% of the students scored above 80, demonstrating the power of music in content assimilation and student motivation. Their motivation increased their concentration and focus on activities, making them less restless and distracted, as is common in this period of life between 12 and 15 years old. By focusing on instrumental practice through percussion, guitar, metallophone, violin, or singing (Figure 5), students were capable to better communicate and express their emotions and affections.
We observed a gender-related issue related to students’ preferences for different musical instruments. A greater number of students self-identified as boys showed more skills with percussion instruments and demonstrated enjoyment in playing genres like pagode, samba, pop rock, baião, axé, march, and funk. On the other hand, students self-identified as girls showed more attachment to singing, violin, and metallophone, together with more inclination towards illustration and dance. These experiences enriched the
classroom environment and allowed a deep understanding of the songs’ contents. Also, choreographies and illustrations produced a more complete integration among the different arts inspired by biosciences’ contents for students from different social backgrounds (Álvares and Amarante, 2016). We sought to use all artistic resources available to foster their interest, higher their focus, and provide more interaction among the students. Thus, they were capable to perceive, visualize, hear, interact, seeking to participate and integrate at the widest range about the themes addressed in the biosongs.

6 CONCLUSIONS

Music plays a crucial role in elementary school education, significantly contributing to the intellectual, social, and personal development of children. Research has demonstrated that active engagement with music in elementary schools can positively impact students’ cognitive abilities, intelligences, emotional well-being, and social interactions (Hallam, 2010). By focusing on basic music learning, fostering an appreciation for music, and imparting fundamental music knowledge, elementary school music education assists students in developing essential skills and functions related to music and cognition (Park, 2022). Furthermore, music classes related to biosciences in elementary schools should be highly valued by both teachers and students to serve as a platform for creativity, self-expression, and personal growth (Lamont et al., 2003). Integrating music into the curriculum through activities like songwriting with the guidance of mentors, such as done here with the biosongs, can enhance students’ musical abilities and encourage artistic self-expression (Gallo and Kuchenbrod, 2022). Music education in elementary schools has been shown to be motivating and advantageous for students, enhancing their overall learning experience (Clark, 2022). Also, the adoption of innovative approaches in elementary music education, such as incorporating rap, hip-hop and digital technologies, can boost students’ creativity, cultural awareness, and engagement with issues of contemporary society and develop their sense of rhythm (Kruse and Gallo, 2020; Desyandri et al., 2021). By integrating technology and multimedia tools, educators can create interactive and engaging music lessons that cater to diverse learning styles and preferences (Desyandri et al., 2021). Together with other research, we have shown that music education in elementary schools not only nurtures musical competence but also contributes to students’ overall development and well-being (Iswara et al., 2020). Thus, music must hold each time a more significant place in elementary school education, providing students with a creative outlet, promoting
cognitive development, and enhancing social interactions. By performing interdisciplinary connections that integrate music into the curriculum of other courses and exploring different musical genres and technologies such as done here with biosongs, elementary schools and teachers can offer students a comprehensive education that nurtures their artistic talents and enriches their overall learning experience.

Further research needs to be addressed to precisely evaluate whether there was indeed an improvement in the academic levels of the students using music-based active teaching-learning, possibly using strict statistical and mathematical tests. Preliminary data collected here suggest that the project’s students have shown improvement in formal evaluations, as well as other less objective parameters, such as fluency, social behavior, and commitment/motivation. Several neuroscientists (Muszkat, 2000; Izquierdo, 2002; Levitin, 2006; Houzel, 2009; Schalaug, 2015; Germano, 2018) have verified the effects of music on the brain and how interdisciplinary approaches allow a relevant intersection between the left and right cerebral hemispheres, invariably resulting in an increase in the corpus callosum through the conscious practice of musical intelligence. We observed benefits that cannot be directly identified by formal tests, motivating us to continue our studies and research. In parallel with the formal results quantifiable by the grades and performance of the students, we collected informal testimonials from the school’s administration, teachers, parents, and the students themselves, reporting qualitative improvements in their learning experience. We are aware that our investigation needs to get deeper so that we will be able to better understand the relationship between adolescent students in elementary school and their cognitive functions, mainly the ones related to music. We aim to understand how music tools can be used in basic courses to provide a dialogue between different schools of knowledge involved in the teaching/learning process, beyond the study of biosciences. Álvares and Amarante (2016) refer to the reunification of fragmented knowledge, showing that society sometimes invests time in specialized details and forgets the broad integration that is key about musical practice. These ideas are also connected with the work of Edgar Morin, a prominent French philosopher and sociologist, known for his complex and interdisciplinary approach to understanding the world (Morin, 2014). In the realm of education, Morin’s theories emphasize the need for a more comprehensive and integrated approach to learning, mainly in the education of adolescents (D’Esposito and Celani, 2017; Oliveira and Alves, 2022). It is our interest to foster a comprehensive perception that unifies knowledge and
the multiple intelligences in the classroom, following approaches by Gardner and Antunes (Gardner, 1983; Antunes, 2009).

Focused on fostering a high-quality school that educates loving and prepared citizens for the challenges that the modern world and society present to us (Teixeira, 1969), we seek to use tools from music and the arts as active teaching-learning strategies to better convey information, stimulate its assimilation, and value affection and emotionality among students, making them protagonists in the educational process (Konopka et al., 2015). Along our research, the artistic skills and activities of the students were shown and valued, leading them to learn scientific content in a more playful and affectionate way, especially in the field of biosciences. Thus, students became more motivated and interested in learning, showing more concentration, memorization, and affection. Their harmonious interaction in the classroom and with their peers created an emotional bond and led them to participate actively and creatively in the construction of pedagogical material (Griggs et al., 2016). Also, the activities foster the individual talents the students have, each being more prone to sing, dance, or play a given instrument. This way, the students were capable to better absorb the content of the disciplines and promote their own musicality by awakening in them their specific musical vocation without being ashamed (Reimer, 1996).

In our view, educational institutions should strive to be more connected with the importance of teaching music and arts in schools, mainly by providing interdisciplinary approaches with life sciences and other theoretical courses. We believe that the therapeutic and empowering potential of the arts has been underutilized as pedagogical resources and can greatly benefit students in elementary school education, with teachers acting also as some sort of psychotherapists (Guerreiro, 2003). As Brazilians, we are a highly musical people, and sometimes where books and other pedagogical tools cannot reach students, perhaps a song, a melody, a rhythm, or a dance can touch deeply the students to facilitate their learning processes. Also, this kind of work involves students’ affectivity and can emotionality transform their lives providing a positive impact to the world, bringing new perspectives to interpersonal relationships and social behavior (Ilari, 2006). Our investigation will continue as the results obtained and reported here are encouraging and give us the conviction that we must continue this work. Finally, it is relevant to perform an active listening to students, professors, and peers so that we can build a more playful, joyful, motivating, and welcoming environment for education in Brazil and worldwide.
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