Use of Music to Enable the Social Inclusion of Deaf Children Using Robotics and Recreational Activities

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Abstract. This project demonstrates challenges encountered in the inclusion of children with hearing impairment in music learning and presents how society sees these children, seeks to know how deaf people see music, presents reports of deaf people who have had contact with music and how it has helped them in society and seeks to evaluate visual elements combined with robotics in the practical teaching performed with deaf children. It is envisioned with this work to present how technology can be a differential in the practice of music teaching and an aid to generate social inclusion of deaf children, allowing their contact with hearing people in all places with audible events.

Keywords: hearing impaired children, deaf community and culture, colorful musical elements, deaf aid technology applications, robotics in music.

1 Introduction

At different moments in history and school policy in Brazil, music education was present in the context, always marked by difficulties, the process of building music teaching was marked by document elaborations and actions that were the result of struggles to insert it in schools. Thus, higher education institutions created undergraduate courses in Artistic Education by legal determination, thus working the teaching of visual, performing, and musical arts. On the other hand, the use of these different languages as consequence generated the weakening of music education in schools, and over time was replaced by only fine arts, which contributed to the disappearance of music as cited [1].

In view of this [2] believes that music should not only be worked as a discipline, but be worked in a thorough way by professionals with solid knowledge of it to pass a solid knowledge to those who study it, she says this because it analyzes that teachers without musical training summarize in practical musical foundations only activities such as singing or musical listening with basic information. Thus it is difficult to imagine that teachers with the ability to teach early beings would have conception of music teaching equally to a teacher prepared and licensed for the teaching of music, because they obtained in their curriculum, the theoretical, practical way, the expressive form of music teaching, and finally one of the most relevant items, acquired techniques to be able to teach the mastery of musical instruments to children as men-

tioned [3], the self still defends how important music is being taught in schools for better cognitive development of children.
The author [3] also proposed some questions to be analyzed in this world of music education in schools, one of them is to analyze the fact that a teacher not licensed in music guiding children, the error inserted in this medium also, of teachers not graduated in music, teach this specific subject in schools. Another factor that is also relevant is the consideration of equality between teachers with musical training or not according to law 11,769 in 2008. Thus, it is intended to seek new alternatives that can help meet these needs in schools in the musical sphere, for this it is necessary to explore the technological means to be as an aid of music learning in schools, in addition there are cases of children with very specific needs, such as hearing impairment, which would be another case study factor for music teaching.
Currently in Brazil there are different types of deficiencies, and it can be auditory that is the theme, or visual, motor, with its degrees of severity. In the case of auditory, according to census data, it reached the third position, lagging the visual, and motor impairment, which occupies the first general position [3].
This research sought to delimit the theme, comprising a search for bibliographic references in relation to the theme, thus we were aware of several articles and books among which we highlight an article of [4] with the name "Deafness and Music: is this a paradox?" where this same author also has a doctoral thesis with the theme "Teaching Music to deaf students: perspectives for inclusive pedagogical action", among the various books analyzed we find the book "The musicality of the deaf: representation and stigma" of the researcher Nadir Haguiara-Cervellini, we had other articles and books used as a theoretical basis, but all the others were musical currents and others pointed to libras learning.
The formation of deaf individuals has broken many paradigms that until a few years ago represented unique models, and has allowed deaf people to have new opportunities, such as going to a cinema, to a park, to school and being able to interact simply, and being able to learn music and feel it like other people.

2 Use of colors in music to aid deaf people

For several years, researchers tried to relate musical notes with colors and even in the old east these relationships were made between these two [5]. We will show below a table where the relationship made by several researchers during the centuries that sought to idealize this relationship between music and colors is presented in Fig. 1:

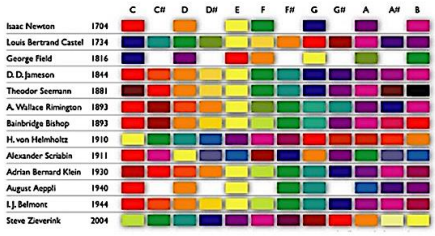


Fig 1. Three centuries of color scales

It is possible to analyze in this table that the relationships do not follow the same pattern between colors and intervals of musical notes, because there were many personal perceptions among the researchers, which means that there was only meaning for those who defined them. For this reason, there is a need for a standardization between music and colors, so that the learning process can be carried out through audiovisuality and show efficiency.
[6] is also used for a relationship between colors and musical notes with purpose in the frequencies of sounds and frequency of colors. With this thought of analyzing the low colors (430x1012) which in this case represents the red with darker tint and making use of the concept of tuning (There 440 Hertz), the researcher noticed that the tone that has the closest relationship would be the SUN that is below the A 392 Hertz. The comparison is perfect, but it is concluded that it is not all frequencies that are equivalent in tones due to the temperate nature of the tuning in the west.
In Fig. 2 we show the Law of the Octaves/Periodic Law, which deal with the underlying ratio of the vibration scale and thus, therefore, is the basis for all theories that relate to the relationships between colors and musical notes (the repetition of the notes on the board means the sharp "#") [6].

Color frequency	*Color name*	*Frequency 40 octaves below*	*note name*	*Freand note quorum*	*Difference*
430 (x 1012)	Red	391,3	Sun	392	0,7
460 (x 1012)	Red / Orange	418,6	Sun	415	3,6
490 (x 1012)	Orange	445,9	There	440	5,9
520 (x 1012)	Yellow	473,2	There	466	7,2
550 (x 1012)	Lemon	500,5	You	494	6,5
580 (x 1012)	Green	527,8	C	524	3,8
610 (x 1012)	Turquoise	555,1	C	555	0,1
640 (x 1012)	Blue	582,3	Defendant	588	5,7
680 (x 1012)	Indigo	618,7	Defendant	623	4,3
720 (x 1012)	Dark Violet	655,1	Mi	669	13,9
760 (x 1012)	Violet Lighter	691,5	Make	700	8,5
800 (x 1012)	Ultraviolet	727,9	Make	742	14,1

Fig. 2. Sound and Color Frequencies

This research becomes interesting because of the musical notes and colors in the music are constituted of frequencies, but there is a problem that the musical note is always a single color or vice versa, so the relationship that the musical note has with a color would have a lot of variation, and every moment would have other colors.
A researcher in the Arts department of PUC-RJ made a relationship between music and colors, in the case of Celso Braga Wilmer (1948). The same has training in visual communication, mathematics, and music, of which were the researcher developed a project to facilitate the learning of reading sheet music as quoted [6].
Wilmer developed a work focused on the musical pedagogical form, focused on the understanding of music through sheet music, so he named his work "Rainbow Score". The aim of this study was to adapt traditional cores to provide a form of ease to music students with established musical symbols, where Wilmer saw themes [7]. abstracts.
Based on the levels of abstraction of learning of Jean Piaget (1896-1980), the project sought to insert the score already existing within a presentation of the chromatic mod-

el that he himself adopted, applying the scales and shades the largest and smallest in its duration, harmonic and melodic, etc. Thus, after the application of Wilmer's project are the degrees of the musical scales that receive the colors and cease to be the tones, as a kind of figure on a background [6]. You can see below how this relationship works in the Fig. 3.

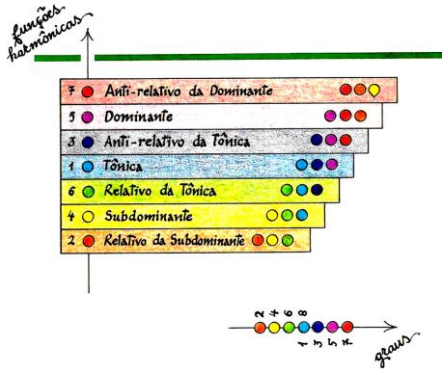


Fig. 3. Harmonic functions with colors.

Still dealing with harmonic functions, the researcher Wilmer made a relationship between musical intervals and colors very different from previous researchers, and so many others of today, the work proposed by the same is somewhat effective, and this can be seen as a great principle for analyzing music using colors, is considered relational character what notes and colors can have in a given music.
Another project that deserves to be mentioned is the "CO. Diesis" which was conceived by the Balearic Islands University in Spain, where it was developed thinking of blind people and works the relationship of colors with sound, where color becomes sound[7]. This work was a pathway for the software "CromoTMusic" that also stands out in this concept.
The principle of work is to transform sounds into colors for blind people, already in the background one has the idea of working on the transformation of musical notes into colors to help deaf people in contact with music. At the point of view of audiovisuality the circumstance cited is very important because we speak of two deficiencies (hearing and vision) that are treated in audiovisuality one of them deafness can be compensated through colors, in the case of contact with music.

3 Methodology

In this project we present to the child's deaf fundamentals of music, such as musical notes, rhythms and tempo of the compass, coming out of the traditional way that makes use only of a book, a blackboard or any other medium other than with the use of technology, in this way will be made the use of the following materials:

- *Mbot robot adapted with a single LED that supports 7 colors / bluetooth.*

- *USB vibratory bracelet could not find a bluetooth bracelet.*
- *Grand piano Roland,*
- *iPad-Pro,*
- *Python language to configure the robot.*
- *Editom for demonstration (SOL clave).*

To achieve the goal in the experiments we will work with a robot integrated with Scratch that is a programming language composed of blocks created by Papert in 2008, and more specifically use it adapted in a version of Makeblock, so we will have the possibility to control the robot and its resources through a mobile device, this can be a mobile phone, tablet or iPad, where children will make combinations in the application.

Before starting any activity with the robot, we will teach the concepts of the project so that children can understand what each item means during the practice of recreational activities, because none of the children has musical knowledge, this in the theoretical and practical scope. In this way we will teach the combinations between colors and musical notes proposed by Wilmer, and musical concept based on BONA which is a book intended for teaching musical concepts.

After the children know the musical notes combined with colors and have a basis of what each color means in the musical pentagram we will move on to the second part of the experiments that concerns rhythmic time, we will insert the concept of musical time in the activities. The child will know the rhythmic time equivalences used in music using the robot's movements.

A group of 7 children aged between 5 and 9 years was selected to do the musical experiment using robotics and playful activities with applications. Among these children 6 have hearing problems and need interpreters to help them in communication and 1 of them listens normally and will be a model for the other children when performing the activities. Throughout the process there was consent of their guardians and we were assisted by 4 monitors who were psychologists and pedagogues who accompanied the children during the moments we met and participated in the experience as evaluators.

Table 1 shows the communication situation of each of the 7 children who participated in the experiments, where the symbol "X" indicates positive, this information was proven during the experiments.

Table 1. Communication situation of each child.

Participant and Age	Reading situation	LIBRAS Situation	Degree of Deafness		
			Moderate	Severe	Deep
Child 1 - 9 years	X				
Child 2 - 6 years					X
Child 3 - 6 years					X
Child 4 - 7 years					X
Child 5 - 7 years					X
Child 6 - 8 years	X	X			X
Child 7 - 9 years	X	X			X

The first contact with the children lasted about 4 hours, for them to become familiar with the proposed scenario and feel at ease it was necessary to do an activity to generate entertainment, so we did an activity with the use of balloons representing the colors of the musical notes that we would use in the application next. So, after the activities with balloons we set up the robot together with the kids as a mode of fun.
In the first stage of the experiments the child listener began to make the first contact with the robot and the other children followed what was done because then the other children would perform the same activity. Thus, the child listener practiced musical concepts.
In the second contact that was a following Sunday it was expected that it would be necessary to remind the children of the colors of the notes and the times that were made the movements of the robot because it had been 7 days, but it was not necessary to do this activity again because the children still remember easily what was proposed in the first activity, this was verified with a simple activity similar to that of the balloons that was performed previously, and through tests with the robot before the experiment of that day.
We started this time by the youngest child to verify that she still had the theoretical concept in mind, even because there was little time spent on the day of the first experiment and so could perform any musical activity similar to another one with little difficulty, this because she imitates the robot during the preparation of the same before the activity that day , which was proven in the participation of the child, she performed the activities without problems.
After the youngest child finished his participation it was the turn of the hearing child to take over the post and do the activities proposed on that day and again be an example for the other children, because soon after all of them they would do the same activity, as we performed in the first experiment.
In order to generate entertainment and the children could have a sense of the experiments for this stage were defined new stages of activities using the application, at that moment we made the use of the song called "Slaves of Job", where each stage of the game in the application in this experiment taught an excerpt of the music and a movement with the musical notes with colors , the steps would end at the time it was played entirely by each child. Just as in the previous activity the other children mimicked the robot's movements and raised their hands for each note presented by the robot.
For the third stage we made the use of the robot that was already used from the first stage, but unlike the other occasions the children would not command the robot via mobile device, but rather the robot would be an indicator that a musical note would be generated from a piano, in case the children pressed anote musical on the piano and the robot presented the color of the note executed on it.
As in the first two experiments the children had no contact with a physical piano, this could generate difficulty for them, so we inserted in this stage of the project a USB bracelet integrated into the robot, so when the children played a musical note on the piano it would vibrate by the fact that it was acoustic, the robot would light the LED indicating the note that was played on the piano and the bracelet would be integrated into the robot generating a vibration in the children's wrist.

We programmed the robot in advance in order to just get to the place and connect it to the piano and get satisfactory response with the notes pressed on the piano keys, so we connected the robot's USB input to the piano. At the time of the experiment of this stage the child should have his left hand on the piano, because it is the hand with the bracelet, she also felt the vibration of the piano, all this occurred in a synchronized way and we sought not to have delays, so as not to generate confusion in the children's heads.

Fig. 4 shows the final scheme of the experiment being performed by one of the children during the third experiment.

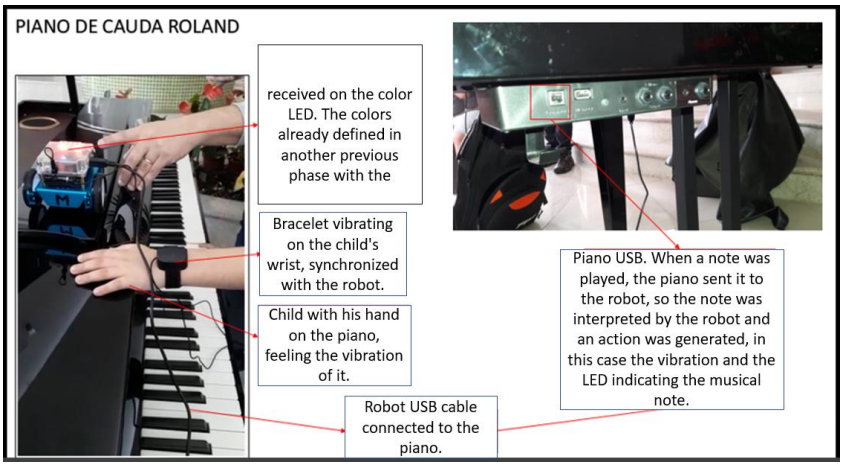


Fig 4. Child playing piano with all the built-in features.

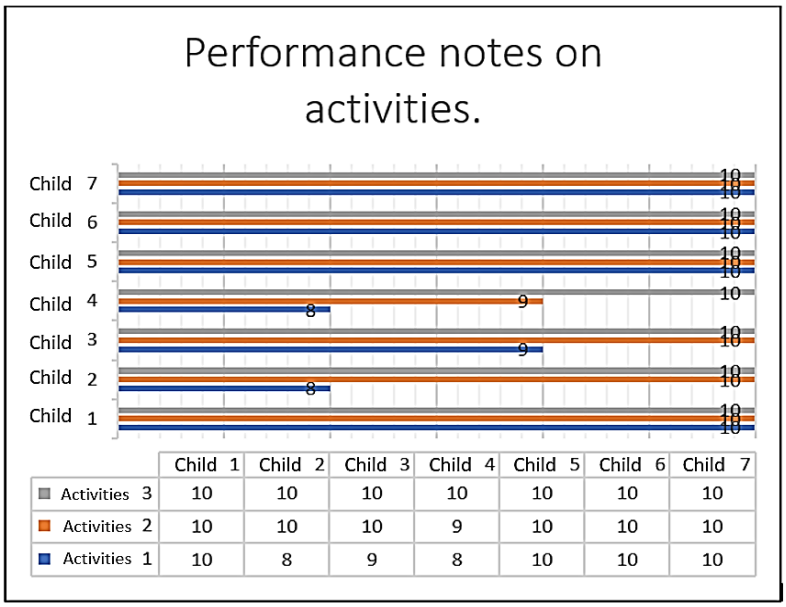
In this third stage we intended to make the children play the same music used in activity 2 when they used the digital piano on the mobile device, which occurred without difficulty. Also as was proposed earlier in the other activities children who were not in contact with the piano should imitate the movements that the robot generated on top of the piano and raise their hands when the notes were performed, an activity that all children performed several times.

All experiments were carried out with the same children, we had the first step we called as experiment 1, the second stage experiment 2 and the third stage of experiment 3.

The activities we developed at all stages explored how children would deal with the concept of colors combined with musical notes, contact with electronic devices and musical rhythm, and evaluate visual and rhythmic issues performed by children when imitating the robot.

All the children performed the same activities in the same period, so it would be possible to know what was the abstraction in relation to the period of participation of all children, knowing where each one managed to get in the application and the time it took.

At all stages the children were evaluated by monitors present at the site, one of the expected specifications would be to know if it was possible for the child to have kept in mind the concept of the activities that were performed previously, and be able to perform the musical concepts, and then know if the younger children could perform the activities more quickly because they had more examples performed before their participation in the execution.
Below is the chart showing Fig. 5 in general how was the performance in children's notes in all activities, so it is better to have a view with the general notes.



	Child 1	Child 2	Child 3	Child 4	Child 5	Child 6	Child 7
Activities 3	10	10	10	10	10	10	10
Activities 2	10	10	10	9	10	10	10
Activities 1	10	8	9	8	10	10	10

Fig. 5. Performance overview in experiments.

According to the results presented in the experiments so far, it can be analyzed that the child was able to learn the musical concepts due to the repetitions of theory and practice, and another relevant factor was the child to see the other children practicing when on their opportunity with the devices, and also with the help of the robot to generate the movements and present the colors as an aider was a differential for the result obtained , so know that something happened while performing a musical note on the iPad.

4 Final considerations

Seeking to see beyond sound, involving different methods to help children in their interpretation of music as use of colors, we also sought to present through the literature review that there is no neurological obstacle that can compromise an individual to have a musical experience, such that the child aims to be able to make use of images and vibrations of devices , thus these items gave us a basis to be able to make a planning of how to achieve the goal allowing to insert applications and hardware in experiments with hearing impaired children.

As soon as we carried out the musical experiments with the hearing impaired children, it was possible to analyze that the architecture used allowed the children to perform the musical activity, thus assisting in the perception of the sounds that happened and that were performed with the compass, vibration and rhythms through the robot.

With this it was possible to reflect on what benefits music played in children through their attitudes in the activities, and how they gave us a positive return with their participation in the activities and also with the feedback we had of them at the end of the activities, the comments of the advisors at the time of the activities, because they were doing the evaluation all the time of the children while they were performing the activities , thus presenting the practical concept that it is possible and pleasurable to teach music to deaf children.

Based on the evaluations and opinions of the advisors who were all pedagogues, it was possible to realize in general that the use of architecture comes to be a great way to be used in the musical activities of deaf children, even for reasons of values that are accessible, and also easy to handle by people even if they are lay people in the subject, with extensive documentation on the WEB the solution used here can be replicated easily for people who wanted to accomplish the same technological context with the documentation available.

The activities performed in this research indicate that the junction that can help provide music learning for hearing impaired children. It presented potential for musical activities and can be adapted to other situations of different visions, thus being able to teach other points in music theory and children learn to have fun.

Thus, it is essential to make use of adaptive technological means in the education of deaf children, verify the effectiveness of the application and hardware, study ways and know what the real impact caused in those who participate in learning.

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