mathematics

MDPI

Article

Influence of Musical Learning in the Acquisition of Mathematical Skills in Primary School

Aurelio Chao-Fernández [1], Dorinda Mato-Vázquez [2] and Rocío Chao-Fernández [1,*]

1 Department of Specific Didactics and Research Methods and Diagnosis in Education, University of A Coruna, 15071 A Coruña, Spain; aurelio.chao@udc.es
2 Department of Pedagogy and Didactics, University of A Coruna, 15071 A Coruña, Spain; m.matov@udc.es
* Correspondence: rocio.chao@udc.es; Tel.: +34-981167000 (ext. 4600)

Received: 29 September 2020; Accepted: 4 November 2020; Published: 10 November 2020

check for updates

Abstract: In this research we analyze the influence of musical activities in the acquisition of mathematical knowledge and skills of a sample, 50 students from both a public and a private school in A Coruña (Spain), at a cognitive level. Based on a quantitative study with a quasi-experimental design, we evaluated students' knowledge acquisition; we worked with musical activities related to mathematics in the experimental group (EG), and with traditional mathematical activities in the control group (CG). We used a questionnaire that the teachers completed before and after putting the activities into practice, after collecting—writing daily field notes—the mathematical knowledge acquired by the students. The results indicate that there are significant differences between the pretest and the posttest, between CG and EG, but there are no differences between public and concerted schools. In short, it is concluded that music represents an excellent tool in mathematical learning.

Keywords: musical activities; mathematics; learning-teaching; preschool

1. Introduction

The close relationship between music and mathematics has been known since ancient times, Pythagoras (582 BC) being considered as the first to establish connections between the two disciplines when joining them in his school, so that music and arithmetic were studied together until the Middle Ages [1].

However, most of the works developed in this area were specific music treatises formulated by mathematicians (Descartes, Mersenne, Euler, D'Alembert, etc.), or compositions created through mathematics (Bartók and the golden reason, Stochastic music by Xenakis, Halffter's Fibonacciana, etc.), being necessary to wait until the end of the 20th century for it to be envisioned as an emerging study area by Milton Babbitt, David Lewin, and especially John Clough [2].

Recently An, Ma and Capraro [3] or Johnson and Edelson [4] have argued the connection between both disciplines claiming that musical notes, scales and tuning are related to various areas of mathematics, from proportions and integers to geometry and trigonometry. That is, most of the theories are built on the relationships and common structures of both components [5], while studies aimed at teaching and learning of mathematics and music at the same time are scarce [6–9]; even more unusual are those reporting the benefits related to teaching them jointly. This is despite the fact that it has been demonstrated, through neuroimaging, that musicians and mathematicians activate common brain areas [10]. In this line, Winner, Goldstein and Vincent-Lancrin [11] made visible an investigation carried out by Graziano, Peterson and Shaw in which they stated that the improvements in the area of mathematics were greater among students who were also studying piano, especially in subjects related to spatial learning.

Undoubtedly, at a neurological level, music provokes different responses in the areas of the brain that affect both cognitive and emotional levels, since it activates imagination and creativity [12], both very necessary to approach mathematical learning from an affective framework [13], building the foundation from which the processes of cognition act: perception, attention, memory, intelligence, thought and language [3,14].

According to studies, the interdisciplinary approach of teaching music with mathematics positively affects cognitive development and skills related to both disciplines and student's academic results [1,15,16]. Some of the reasons may be that learning is more attractive when the contents are addressed together, which provides emotional security and confidence [17,18]. Benefits are significantly increased if interdisciplinary work begins in the first stage of the education system.

In spite of the above, the contributions, experiences and teaching materials that work between subjects at school in an interdisciplinary way [19] are solely incipient, except for the occasional song to facilitate the processes of memorization of, for example, the multiplication tables. This trend also occurs in Spain, which does not come as a surprise, since an absolute disconnection among the same course subjects is usual [10]. Although the Organic Law 2/2006 of Education of May 3 [20] organizes the curriculum of Infant Education in Spain in three areas of knowledge, indicating that the work must be done in an interdisciplinary manner, it is quite different in real-world scenarios [21].

There are two types of schools depending on their ownership: public and private since 1985, according to the Organic Law Regulating the Right to Education [22]. There is plenty of research that analyzes whether there are differences between both types, the results being torn between those that do find different results [23,24] and those that conclude that there is no significant difference in relation to the ownership of the center [25–27] and claim other inputs to be more relevant.

The edition of PISA [28] goes one step further by adding two parameters: the appreciation of the students (their satisfaction is greater when they study in charter and private centers than in public centers) and the performance in the evaluations (which is lower in public schools).

Calero and Waisgrais [29], Meunier [30] and Salinas and Santín [31] among others justify the differences in academic performance in public centers due to the lower quality of resources and the greater number of students of immigrant origin.

From this referential framework, we have asked ourselves the following research question: How does music and, more specifically, music teaching, influence students' mathematical learning?

The presented work is part of a larger study that analyzes the effects, cognitively, of musical activities in math classes, and how these scaffolds influence student learning depending on certain variables such as the course, sex, ownership of the center, professions and studies of parents [32].

Particularly, the objective of this research is to analyze the influence caused by musical activities, cognitively, in the acquisition of mathematical knowledge in the last course of Pre-school Education, taking into account the ownership of the center.

2. Materials and Method

To analyze the influence on the acquisition of mathematical knowledge, a quantitative methodology has been used, based on a quasi-experimental design with a pretest and a posttest and two reference groups: an Experimental Group (EG), which received the stimulus or treatment; and the Control Group (CG), which only served as a comparison since it did not receive such treatment.

2.1. Context and Participants

The study involved a sample of 50 children between 5 and 6 years old, 25 girls (G) and 25 boys (B), 24 from a Public School (PS) and 26 from a Charter school (CS) of the 3rd year of Early Childhood Education in the province of A Coruña (Spain) and their respective teachers in the school year 2018–2019 (see Table 1). Besides, in this research, centers with similar socio-economic characteristic were selected to avoid possible influences.

Table 1. Distribution of the sample.

	SEX	AGE	CG	EG	Total
PS	G	5	2	3	24
		6	4	3	
	B	5	3	4	
		6	3	2	
CS	G	5	3	3	26
		6	4	3	
	B	5	4	4	
		6	3	2	
	Total		26	24	50

2.2. Procedure

The research carried out refers to a pretest and posttest design. The purpose is to evaluate the mathematical learning before and after the intervention of the teachers to be able to subsequently make a statistical comparison between the students' learning and the possible variations depending on the two groups into which the sample was divided (the CG formed by 26 students and the EG by 24), and the ownership of the center to which they belonged (in the CG, 12 students belong to PS and 14 to CS, and in the EG, 12 to PS and 12 to CS).

In order to obtain the data, the same contents were worked on in both groups, although, to verify if there were differences in the academic results of the students, preselected musical resources were used in certain activities within the classroom—related with mathematics contents—with the experimental group (EG), while with the control group (CG) mathematics content was worked with traditional didactics.

The mathematical contents developed with the strategy of the musical activities worked in the classroom, and with the respective teachers, deal with "Properties of the objects" (PO), "Basic operations with concrete elements" (BO) and "Space-time relations" (STR) and have been elaborated from Decree 330/2009, currently in force in the Autonomous Community of Galicia (Spain).

2.3. Evaluation

The evaluation technique that was used was direct observation; that is to say, the progress of the students during the accomplishment of the programmed activities was contemplated, focusing mainly on the acquired learning, as well as on the rhythm and characteristics of this acquisition. That is why in this work we collected, through field notes, relevant descriptive and reflective information by the teacher-tutors in the day-to-day process. This systematic collection resulted in a class diary of each student that allowed to cover a questionnaire designed by the researchers that would make up the pretest and the posttest.

The questionnaire consisted of 10 items with six response options, ranging from 0 (nothing) to 5 (much), to evaluate some fundamental contents of the mathematics based on LOE [20]. It was then endorsed by a system of inter-rater validation formed by four experts (teachers and professors specialized in mathematics and music). In this way, the most relevant items were selected for their relevance (they should be related to the object of study) and clarity (easily understandable).

The items of the questionnaire are the following:

I_1. To recognize circles, triangles and squares.
I_2. To order objects by size.
I_3. To classify daily use objects by their shape.
I_4. To arrange objects by their height.
I_5. To group items by quantity.

I_6. To create compositions with Cuisenaire rods.
I_7. To associate the numerical name with the number of elements.
I_8. To identify morning, afternoon and evening.
I_9. To use different measuring units.
I_{10}. To recognize before-now-after.

The distribution of the items of the questionnaire regarding the contents worked in the classroom is as follows: PO (I_1, I_2, I_3, I_4), BO (I_5, I_6, I_7), and STR (I_8, I_9, I_{10}).

After the pretest was carried out by the teacher-tutors (in the Spanish educational framework it is the Infant teacher/tutor in charge of teaching music) and the analysis of the data by the researchers, an activity plan was prepared related to the mathematical contents mentioned above (PO, BO and STR), which would be developed three days a week, 30 min per session, for two months with the EG, while in the CG the class sessions related to the same contents were held in a traditional way (cards and textbook). The participating teachers are part of an interdisciplinary research group led by the researchers and had already collaborated in past courses on other innovative experiences with other students. Therefore, the training they had, prior to the start-up of this project, was forged jointly in the whole group, which led to the design of the proposal being developed by all.

At the end of the 8 weeks, and after the achievement of the activities, the teachers—with all the data from the daily observations—covered the posttest test in both groups (Experimental and Control) to determine if the treatment had brought any change in the acquisition of mathematics knowledge. Finally, the tabulation of the data, the statistical analysis and the discussion of the results by the researchers was carried out using the statistical package SPSS v.23.0. Averages and standard deviations were used as descriptive statistics, the Cronbach's alpha is used to find the reliability coefficient, the Wilcoxon T test, appropriate for related variables, and the Student's *t*-test for independent variables. The reliability coefficient obtained by Cronbach's alpha (internal consistency) is satisfactory with values of 0.803 in the pretest and 0.821 in the posttest; for the control group 0.811 and 0.892 for the experimental group, as well as 0.796 for the Public School and 7.01 for the Concerted School.

The development of work with the EG was carried out by formulating a logical sequence of activities structured in sessions using musical instruments, songs, choreographies, working duration, height and intensity, in addition to any situation of interaction with schoolchildren that would respond to their questions.

Each of the sessions consisted of three phases: (1) in the general assembly, an introductory activity was carried out in order to check the previous knowledge, present the contents and stimulate the students. We tried to incite them to action based on what they knew; (2) the development activities were carried out, in which the children demonstrated what they were learning in the previous phases, and (3) finally, the relaxation phase is the highlight in which relaxation tasks were carried out, but without losing connection with the central theme of the program.

Taking Noll [33] into account, all the proposed activities had a playful nature, since at these ages the engine of emotional, intellectual and social developments are games. In addition, they influence knowledge structures and relationships with the environment.

It should be noted that the teacher made an effort to promote a climate of security and trust. At all times, the teacher worried about helping the students when developing the activities, reminding them of the collective rules and guiding those who were blocked by providing them with new patterns of action.

Since music is attractive to students, even more so at early ages, we have proposed a series of musical activities that motivate them to progressively relate them to mathematical concepts. These examples show an example of how the quality of the sound "Duration" has been worked from music and mathematics in an interdisciplinary manner.

2.4. Musical Games

The musical race
Objectives:

- To learn certain musical figures (half note/minim, quarter note/crotchet, eighth note/quaver, rests).
- To understand that each figure has a duration.

Work group: the whole class.
Resources: the song *The musical race.*
Time: 15 min.
Description: We listen to the song The musical race. After the first time, we ask students about figures: did all they run at the same speed? Which one was the fastest? Which one was the slowest? Then, we listen to the song again, this time imitating the figures that are part of the race.

In this activity, through the listening, students have to get to learn, and understand the duration of musical figures (half note, quarter note, eighth note, quarter note rest). Afterwards we check whether that knowledge has been acquired through questions, and finally, through movement, students try to link them to the mathematical concept "Fast-slow", through the experience of a race where they imitate the slower and faster musical figures.

Simon Machine
Objectives:

- To follow a sequence of sounds.
- To obtain a faster or slower sequence of sounds.

Work group: Groups formed of 4 to 5 children.
Resources: Simon machine.
Time: 30 min.
Description: Randomly, the machine illuminates and emits its own sound as it lights. After waiting, the student must repeat the sequence offered by the machine, in the correct order, using theirs visual and audible memory. If the student succeeds, the machine will respond with a longer sequence, and so on. If the student fails, the student must assign his turn to the next classmate. The different levels of difficulty increase the speed of the sequence to be repeated.

In this activity, in addition to trying to involve the student in interdisciplinary work-through the "Fast-slow" sound sequence-it is intended to improve memory, attention and concentration, increasing the difficulty progressively.

Musical domino
Objectives:

- To understand the time that each figure occupies.
- To be able to reproduce the time that figures last by clapping.

Work group: the whole class.
Resources: adapted domino.
Time: 20–25 min.
Description: The domino consists of the following figures: whole, half, quarter, eighth notes and quarter rest, in two colors (red and black). Each student takes 6 tiles that are placed face down. The one that gets the tile with two half notes begins.

The students will have to join the tiles, for example, black red-black red, and they will then clap taking into account the time that each figure occupies; in this case, the student will count to one. When it comes to the silence tile, the student will not clap, but will just wait for the necessary time. The first to finish the tiles wins.

This activity includes the musical figure known as the whole note which implies more difficulty than previous tasks since it is necessary having understood the concept of duration related to quantity.

Let's dance!
Objectives:

- To be able to remember a sequence.
- To internalize ordinal numbers.

Work group: the whole class.
Resources: music player.
Time: 15 min.
Description: There will be a brainstorm of the steps that students want to introduce in the choreography. Once the steps have been proposed, a selection is made and they will be adapted to a song known to children. This was one of the choreographies:
First: We all jump once.
Second: We turn to our right twice.
Third: We move the arms up in circles 3 times.
Fourth: We move the hip to the right and left 4 times.
Fifth: We cover our nose and crouch 5 times.
Repeat as many times as necessary as the children want.
This activity was one of the most attractive for students, since in addition to having fun, they consolidated the musical and mathematical knowledge that the class had been working on, and other activities were added such as laterality, numbering, geometric figures, etc.

3. Analysis and Results

3.1. Averages and Standard Deviations of the Pretest and Posttest by Groups and Ownership of the Center in the Respective Items

The averages and standard deviation show that, with respect to the initial and final tests, there are differences in the academic performance of the Experimental Group, compared to the results obtained by the participants of the Control Group according to the ownership and regarding *I1* (Table 2).

Table 2. Averages and standard deviations of the scores obtained in all Items by group and ownership.

				I1	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	*I9*	*I10*
PS	*Pretest*	CG	M	2.57	1.93	3.25	3.11	1.85	3.66	2.86	2.23	2.85	2.75
			SD	±0.65	±0.79	±0.88	±0.1.23	±0.67	±0.1.36	±0.85	±0.75	±0.85	±0.55
		EG	M	2.50	1.65	2.90	2.84	1.86	2.96	2.75	2.34	2.99	1.87
			SD	±0.51	±0.71	±0.45	±0.87	±0.65	±0.65	±0.65	±0.67	±0.54	±0.80
	Posttest	CG	M	2.74	2.69	3.58	3.52	2.67	3.84	2.90	2.65	2.83	3.02
			SD	±0.68	±0.85	±0.84	±0.143	±0.97	±0.127	±0.85	±0.95	±0.78	±0.41
		EG	M	3.89	3.99	4.34	4.11	4.96	4.30	4.89	4.86	3.12	4.91
			SD	±0.1.52	±0.65	±0.58	±0.76	±0.1.11	±0.85	±0.65	±0.141	±0.76	±0.1.01
CS	*Pretest*	CG	M	2.43	2.16	3.21	3.31	1.96	3.39	3.01	2.31	2.12	2.86
			SD	±0.83	±0.16	±0.12	±0.1.62	±0.83	±0.124	±0.23	±0.87	±0.12	±0.72
		EG	M	2.41	1.23	2.81	2.81	1.92	2.91	2.27	2.11	2.81	1.83
			SD	±0.40	±1.12	±1.28	±0.54	±0.76	±0.43	±1.36	±0.85	±1.21	±0.46
	Posttest	CG	M	2.74	2.51	3.51	3.49	2.74	3.78	3.19	2.83	2.01	3.13
			SD	±0.68	±0.87	±0.87	±1.61	±0.87	±1.00	±0.99	±0.76	±0.89	±0.42
		EG	M	4.73	3.87	4.45	4.29	4.82	4.51	4.83	4.33	2.68	4.82
			SD	±1.19	±0.83	±0.82	±0.1.01	±0.1.36	±0.1.01	±0.76	±0.1.01	±0.87	±0.1.32

Note: M = Mean value; SD = Standard Deviation.

It is stated that the performance in CS has experienced an improvement in the EG (went from 2.41 to 4.43), while in PS (went from 2.50 to 3.89) an improvement is also reflected, although less than in the CS.

The starting scores were higher in the PS. However, in the posttest score the scores obtained by the CS are higher (Table 2).

As it can be seen in Table 2, the scores obtained in the I_2 (to order objects by size) reveal that the EG, starting from very low marks in the *pretest*, has improved more than the CG. If we compare by ownership, we see that in the CG, the students of the PS had lower averages in the *pretest* and higher in the *posttest*. On the other hand, in the EG the scores of the PS sample were and continue to be higher.

The values, in general terms, indicate that the participating sample has a positive attitude towards the use of musical activities in the teaching–learning process of mathematics as shown in the results of Table 2. In this sense, there are differences between CG and EG, in favor of the latter in all cases. The students of the CS stand out again, although all of them experience an increase in their grade (Table 2). While the CG averages are homogeneous in both centers and in both tests, in the EG the differences were greater in the students of the PS at the beginning of the project, but the students of the CS showed superiority in the second test.

Concerning averages and standard deviations of the I_4, we obtain higher values in all cases when the questionnaire is passed a second time. Differences are shown between the Control and Experimental groups—in favor of the first in the pretest and in favor of the second in the posttest—in both centers (Table 2).

In the case of I_5, the EG stands out again with respect to the CG in the posttest result, which analyzes the grouping of elements according to the quantity. Starting from the averages in the initial tests—in which the CS stood out slightly in both groups—the CS CG stood out in the posttest, although in the EG there is a small inclination towards the PS. In addition, if the results are assessed before and after the application of the activities, it is necessary to highlight that the results of the pretest were low in general, while those of the EG posttest are very high, with the PS students reaching scores very close to 5 (Table 2).

In I_6, the average scores obtained by the students according to the interdisciplinary method reflect differences between the CG and the EG, in favor of the latter in all cases. Comparing the results to the type of center being analyzed, the students of the CS stand out again, although all of them experience a increase in the grade (Table 2). While the CG averages are homogeneous in both centers and in both tests, in the EG the differences between the schools were higher in those belonging to the PS at the beginning of the project, but those of the CS showed superiority in the second test. The obtained data are shown in Table 2.

Another aspect included in the instrument used refers to associating the numerical name with the quantity of elements embodied in the responses of item 7 with an average close to the response value 5 (=4.89 and 4.83) equivalent to "Totally agree" in the GE of the PS and the CS.

Based on Table 2, the mean and standard deviations of the scores obtained by group and center typology express that the CG of the CS experienced a slight improvement and no change is perceived in the PS students. Additionally, the EG improved meaningfully and in a special way in PS and CS, since the scores of the initial questionnaire were higher than in the CG than in the EG for both centers. Therefore, it can be inferred that musical activities have been of great benefit to students.

Regarding the question of whether they identify the morning, afternoon or evening, which is shown in Table 2, the analysis show that students quantify it as very positive with values that approach the response 5 (x = 4.86 and 4.33) relative to the option "Totally agree". These results confirm that the perception of the participating students about the intimate relationship between music and mathematics follows the same line of the previous Items regarding ownership and the two groups. While the initial values were homogeneous in PS and CS, in the posttest the EG gets distanced from the CG with noteworthy differences; especially those of the PS are on the verge of the maximum score, although it is true that they started from higher values than those of the CS (Table 2).

Regarding I_9, dissimilar results were found, which contrast with the other values of the study. Such data contrast with the previous values; reflected in Table 2, that in the EC the values in the posttest have decreased in relation to the pretest, both in the CG and in the EG. However, in PS the results increased somewhat in both groups. The reasons given by the teachers of the CS to explain this were convincing, alluding to a very negative family event that had happened to one of the students, which affected the rest of the students.

In reference to I_{10}, which assesses the knowledge of the sample on the fact of recognizing before, now and after, it should be indicated that considering the I_{10} content, the averages and standard deviations of the scores obtained show again that the EG improved in all centers, so we can affirm that the effects of the program of recreational musical activities applied to assess the mastery of the students are noteworthy and positive. In Table 2, we can confirm that the EG started from lower values than the CG in both schools; however, the posttest shows better grades in the EG, mostly in the students of the PS.

3.2. Control Group in Each of the Items

Another aspect analyzed is the comparison of the pretest and posttest between the means obtained by the Experimental Group and the Control Group in each of the items. These results lead us to corroborate that the effects of the program of musical activities focused on mathematics are positive and significative on the performance of the students in all the items that were applied to assess the mastery of basic concepts of mathematics (Figure 1). The initial values of the EG are lower than those of the CG in all items except *I9*, although in *I1*, *I5*, *I8* and *I10* there are few differences between one group and the other. In *I9*, the average mark in the EG pretest is somewhat higher than in the CG. Once the posttest was administered and analyzed, we could see from the obtained results that the EG improved in all the items, especially highlighting the *I1*, *I5*, *I7* over the CG. The *I9* item does not offer high scores in any case for reasons of internal nature, which the teachers kindly explained.

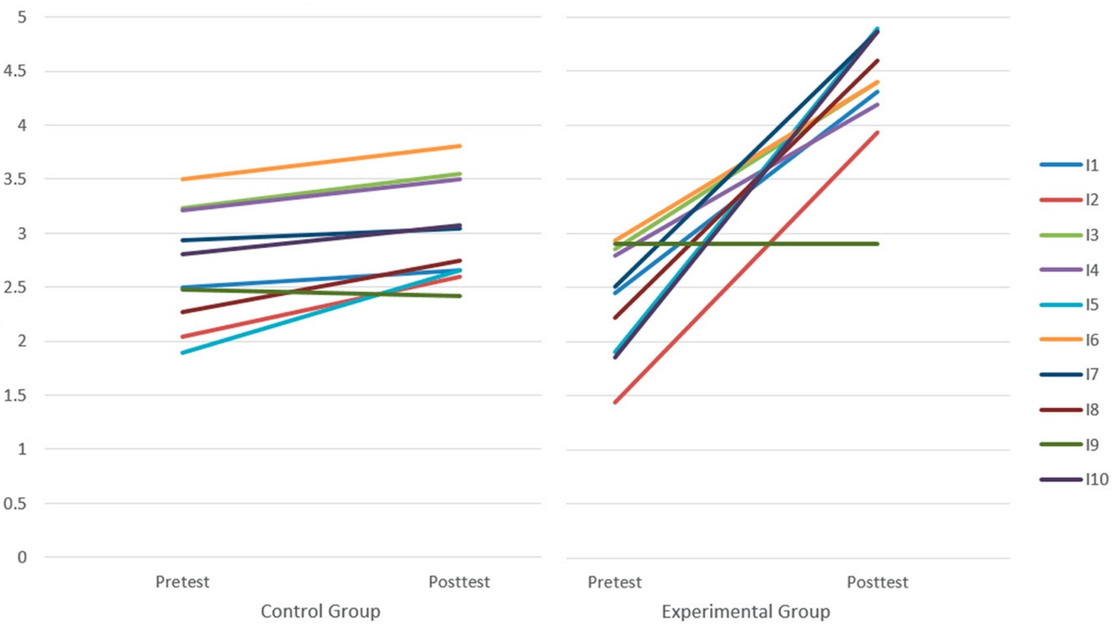

Figure 1. Group interactions by item.

3.3. Comparisons of the Pretest and Posttest between the Means Obtained by the Experimental Group and the Control Group in Each of the Contents

The obtained results, in relation to the worked contents and the groups that make up the study sample, offer the following data: the EG presents worse qualifications in the pretest than the CG in all cases; however, by applying the second questionnaire, the CG increased its performance values on a regular basis and the EG had an important improvement.

The interaction of groups and measurements for performance by content in the pretest—both in the CG and in the EG—show that BO (*I5*, *I6* and *I7*) is the highest, followed of PO (*I1*, *I2*, *I3* and *I4*) and finally STR (*I8*, *I9* and *I10*). Likewise, the posttest also shows that both the EG and the CG remain the highest BO, followed by PO and then STR.

3.4. Comparisons of the Global Means of the EG and CG

It follows that according to the global results, the total averages of the CG (2.67) and the EG (2.36) show higher values in the GC in the pretest. However, the scores of both groups in the posttest differ quite in favor of the EG, with 4.35 for the EG and 2.99 for the CG.

We can therefore affirm that the applied measures had a positive impact, which is in line with other studies that have shown the effectiveness of music to stimulate cognitive functioning [34,35].

3.5. Comparisons of Means for Related Samples

The results obtained in the pretest and posttest were analyzed to check if there are statistically significant differences, through the Wilcoxon test for related samples. Through this analysis, we intend to contrast the null hypothesis of non-existence of significant differences between the means of the subjects before and after applying the proposal of musical activities in the mathematics class.

Observing the results of Table 3, we can verify that the statistic with its associated p-value (0.000) is less than the level of significance (0.05), which allows us to conclude that, between the means obtained in the pretest and the posttest, there are statistically significant differences, favorable to the posttest.

Table 3. Comparisons of means for pretest and posttest.

		Ranges			Contrast Statistics [a]	
		Cases	**Mean Range**	**Sum of Ranges**	**Z**	**Sig. Asint. Bil**
Posttest Pretest	Negative Positive	26 24	2.54 3.67	66.3 88.08	−2.201 [b]	0.000

[a] Wilcoxon signed rank test; [b] Based on negative ranges.

3.6. Comparison of Means for Independent Samples

Next, we proceed to apply the Student's t-test for independent samples, given the parametric nature of the distribution, in order to determine if there is a significant difference between the results of the Public School and the Concerted School, on the one hand, and the Control Group and the Experimental Group on the other.

In both cases, the first assumption of normality is verified, based on the Shapiro-Wilk test, applicable for $n < 30$, since the data have a normal distribution. Additionally, the second assumption, consisting of determining the existence of equality of variances, using Levene's test, resulted in the variances being equal.

When analyzing the data (Table 4), it is observed that there is no significant difference between the mean of the two groups, PS and CS, as p-value = 0.470 > 0.05.

Table 4. Equality of means between the Public School (PS) and the Concerted School (CS).

	Cases	Means	p-Value
PS CS	24 26	3.1375 3.0775	0.470

However, there are significant differences between the CG and the EG, since p-value = 0.000 is less than 0.05, which is why differences are shown in favor of the EG (Table 5).

Table 5. Equality of means between the Control Group (GC) and Experimental Group (GE).

	Cases	Means	p-Value
CG	26	2.8525	0.000
EG	24	3.3625	

4. Discussion and Conclusions

The results obtained in this research have allowed us to identify the influence of musical activities (musical instruments, songs, choreographies, working duration, height and intensity, in addition to any situation of interaction with schoolchildren that answered their questions) in the acquisition of mathematical knowledge of students in Early Childhood Education. We can therefore affirm that the objective we set ourselves at the beginning of the study has been fulfilled and corroborate what authors such as Hall [36] are right to point out about the benefits of interdisciplinary work between mathematics and music. Taking into account the results according to the variables group and ownership, we can affirm that the musical teaching has promoted advantages in the mathematical learning of the students.

We can emphasize that, as for the previous mathematical knowledge that the schoolchildren possessed, the sample is homogeneous in both cases with respect to I_1 "To recognize circles, triangles and squares", To I_6 "To create compositions with Cuisenaire rods", to I_8 "To identify morning, afternoon and evening" and I_2 "To order objects by size".

However, differences between groups can be seen in I_{10} "To recognize before-now-after" and in I_4 "To arrange objects by their height". In relation to ownership, there are differences in I_9 "To use different measuring units", I_7 "A To Associate the numerical name with the number of elements" and I_5 "To group items by quantity".

Focusing on the two groups (CG and EG) and the 10 items of the questionnaire, we achieved that the EG showed greater success compared to the first application of the questionnaire, substantially improving compared to the CG, which remained stable or increased its performance minimally. Specifically, the improvement highlights in items 1, 5, 7 and 8, being 8 the one in which a greater difference was evidenced. In items 2, 4, 6, 9 and 10, the CG had better qualifications in the pretest than the EG, however, in the posttest the EG stood out.

Based on the ownership and the items, in general, we appreciate positive effects of the program of musical activities on the performance of the students in the 10 items. In the case of I_9, the average of the posttest performance in PS and CS of the CG decreased, and it increased minimally in the EG, but it was due to a valid and consistent justification, according to the teachers.

With respect to the two groups and contents, the results indicate improvement in the EG with respect to the CG in the three contents: objects properties, basic operations with concrete elements, and space-time relationships.

Likewise, the non-parametric tests reaffirm the aforementioned, giving results that indicate significant differences between the results of the test prior to the implementation of the proposal and the one after it Wilcoxon's T). Regarding the CG and the EG, it is perceived through the Student's t-test that the EG (who received the math class through musical activities) presents significant differences with respect to the CG, in favor of the former. Finally, it should be noted that the Student's t-test, in relation to ownership, shows that there are no significant differences between public and concerted schools. This shows that the differences are not due to the type of school, or the students, but are linked to the fact of working on mathematics through musical activities.

Consequently, it can be concluded that the activities applied had a positive effect, in line with other studies that have shown the effectiveness of rhythmic patterns, intensities, durations, heights, speeds, symmetry, etc., as effective musical mechanisms in the acquisition of mathematical skills [10]. The present investigation echoes these findings and extends them by showing evidence of such benefits in childhood education, age at which studies are not frequent, as the previous authors indicate, in addition to warning that further research is necessary.

It becomes evident after the implementation of this experience the fact that the application of musical activities as a resource in mathematical learning represents an excellent alternative for teachers of Early Childhood Education, who seek to meet the learning needs of children in a fundamental stage for their integral development. In this way, the proposed objective has been achieved, which is an important contribution to the progress of the interdisciplinary work of both subjects.

In short, the basic knowledge of mathematics was achieved through guided and planned musical experiences, which allowed students to be stimulated in a pleasant and conductive environment, since the activities were carried out with high levels of motivation, harmonizing all their dimensions, both physical and emotional. Therefore, we can affirm that for these teachers music represented an excellent alternative, since it had a positive impact on the performance and motivation of the children in these classrooms. Consequently, we confirm that learning should occur in an interdisciplinary and pleasant context. In addition, it must be adapted to the needs that schoolchildren have to explore and get to know their surroundings. Finally, it becomes clear that professionals trained in mathematics didactics and musical didactics are necessary to undertake this challenge [37].

Author Contributions: Conceptualization, R.C.-F. and D.M.-V.; Methodology, software investigation and resources, R.C.-F., D.M.-V. and A.C.-F.; Formal analysis, A.C.-F., R.C.-F. and D.M.-V.; Writing of the manuscript, R.C.-F., D.M.-V. and A.C.-F.; Supervision project, A.C.-F., R.C.-F. and D.M.-V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: This project is related to the research stay of Rocío Chao-Fernández at the University of A Coruna where she investigated the interdisciplinary work of music and mathematics at school, for which she has obtained funding from the University of A Coruna.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jones-Lewis, S.D. The Impact of Non-Band Music Participation on the Academic Achievement of 6th Grade Mathematics Students. Ph.D. Thesis, Liberty University, Lynchburg, VA, USA, 2015.
2. Yust, J.; Thomas, M.F. Introduction to the special issue on pedagogies of mathematical music theory. *J. Math. Music* **2014**, *8*, 113–116. [CrossRef]
3. Song, A.; Tingting, M.; Capraro, M. Preservice teachers' beliefs and attitude about teaching and learning mathematics through music: An exploratory study. *Sch. Sci. Math. J.* **2011**, *111*, 235–247. [CrossRef]
4. Johnson, G.; Edelson, J. Integrating music and mathematics in the elementary classroom. *Teach. Child. Math.* **2003**, *9*, 474–479.
5. Gareth, R. *From Music to Mathematics: Exploring the Connections*; Jonhs Hopkins University Press: Baltimore, MD, USA, 2016.
6. Graziano, A.; Peterson, M.; Shaw, G. Enhanced learning of proportional math through music training and spatial-temporal training. *Neurol. Res.* **1999**, *21*, 139–152. [CrossRef] [PubMed]
7. Montiel, M. Un experimento piloto sobre la enseñanza interdisciplinaria integrada a nivel universitario: Matemáticas y música. *Foro de Educ.* **2017**, *15*, 1–30. [CrossRef]
8. Scripp, L. An overview of research on music and learning. *Crit. Links Compend.* **2002**, 132–136. Available online: https://www.researchgate.net/publication/245362946_An_overview_of_research_on_music_and_learning (accessed on 20 August 2020).
9. Vaughn, K. Music and Mathematics: Modest Support for the Oft-Claimed Relationship. *J. Aesthetic Educ.* **2000**, *34*, 149–166. [CrossRef]

10. Casals, A.; Carrillo, C.; González-Martín, C. La música también cuenta: Combinando matemáticas y música en el aula. *Lista Electrón. Eur. Música Educ.* **2014**, *34*, 1–17.
11. Winner, E.; Goldstein, T.; Vincent-Lancrin, S. *El Arte Por el Arte? La Influencia de la Educación Artística*; OCDE Publishing: Paris, France, 2014.
12. Kochavi, J. Musica Speculativa for the Twenty-First Century: Integrating Mathematics and Music in the Liberal Arts Classroom. *J. Math. Music* **2014**, *8*, 117–123. [CrossRef]
13. López-Chao, V.; Mato-Vázquez, D.; Chao-Fernández, R. Análisis confirmatorio de la estructura factorial de la ansiedad hacia las matemáticas. *Rev. Investig. Educ.* **2020**, *38*, 221–237. [CrossRef]
14. Song, A.; Capraro, M.M.; Tillman, D. Elementary Teachers Integrate Music Activities into Regula Mathematics Lessons: Effects on Students' Mathematical Abilities. *J. Learn. Arts Res. J. Arts Integr. Sch. Commun.* **2013**, *9*, 1–19. [CrossRef]
15. Fernández-Carrión, M. *Música y Matemáticas: Conexiones Curriculares Para un Mayor éxito Educativo*; 2011. Available online: http://recursostic.educacion.es/artes/ (accessed on 24 September 2020).
16. Chao-Fernández, R.; Mato-Vázquez, D.; Chao-Fernández, A. Fractions and Pythagorean Tuning—An Interdisciplinary Study in Secondary Education. *Mathematics* **2019**, *7*, 1227. [CrossRef]
17. Chao-Fernández, R.; Mato-Vázquez, D.; López-Chao, A. Se trabajan de forma interdisciplinar música y matemáticas en educación infantil? *Educ. Pesqui.* **2015**, *41*, 1009–1022. [CrossRef]
18. Del Río-Guerra, M.S.; Martin-Gutierrez, J.; López-Chao, V.; Flores, R.; Ramirez, M. AR Graphic Representation of Musical Notes for Self-Learning on Guitar. *Appl. Sci.* **2019**, *9*, 4527. [CrossRef]
19. Hughes, J. Creative experiences in an interdisciplinary honors course on mathematics in music. *J. Math. Music* **2014**, *8*, 131–143. [CrossRef]
20. *Ley Orgánica 2/2006, (LOE) de 3 de Mayo, de Educación, Núm. 106*; Boletín Oficial del Estado: Madrid, Spain, 2006; pp. 17158–17207.
21. Román-García, S.; Mato-Vázquez, D.; Chao-Fernández, R. La escuela infantil del siglo XXI: Interdisciplinariedad en el aula? In *Retos Docentes Universitarios Como Desafío Curricular*; Rodríguez Torres, J., Ed.; McGraw Hill Education: Madrid, Spain, 2016; pp. 687–704.
22. *Ley Orgánica 8/1985, (LODE) de 3 de Julio, Reguladora del Derecho a la Educación, Núm. 159*; Boletín Oficial del Estado: Madrid, Spain, 1985; pp. 21015–21022.
23. Calero, J.; Escardíbul, J.O.; Choi, A. El fracaso escolar en la Europa mediterránea a través de pisa-2009: Radiografía de una realidad latente. *Rev. Española Educ. Comp.* **2012**, *19*, 69–103. [CrossRef]
24. Mato-Vázquez, D.; Chao-Fernández, R.; Ferreiro, F. Análisis estadístico de los resultados de las pruebas de rendimiento académico del alumnado de la ESO, participante en los premios extraordinarios. *Rev. Española Orientac. Psicopedag.* **2015**, *26*, 25–43. [CrossRef]
25. Witte, J. Private school versus public school achievement: Are there findings that affect the educational choice debate? *Econ. Educ. Rev.* **1992**, *11*, 371–394. [CrossRef]
26. Cordero, J.M.; Crespo, E.; Pedraja, F. Rendimiento educativo y determinantes según PISA: Una revisión de la literatura en España. *Rev. Educ.* **2013**, *362*, 273–297. [CrossRef]
27. Coleman, J.; Hoffer, T.; Kilgore, S. *High School Achievement: Public, Catholic and Private Schools Compared*; Basic Books, Inc., Publishers: New York, NY, USA, 1982.
28. OECD. *PISA 2009 Technical Report*; PISA OECD Publishing: Pisa, Italy, 2012.
29. Calero, J.; Waisgrais, S. Factores de desigualdad en la educación española: Una aproximación a través de las evaluaciones de PISA. *Pap. Econ. Española* **2009**, *119*, 86–98.
30. Meunier, M. Immigration and student achievement: Evidence from Switzerland. *Econ. Educ. Rev.* **2011**, *30*, 16–38. [CrossRef]
31. Salinas, J.; Santín, D. Selección escolar y efectos de la inmigración sobre los resultados académicos españoles en PISA 2006. *Rev. Educ.* **2012**, *358*, 382–405.
32. Mato-Vázquez, D.; Chao-Fernández, R.; Chao-Fernández, A. Efectos de enseñar matemáticas a través de actividades musicales. *Relime* **2019**, *22*, 163–184. [CrossRef]
33. Noll, T. Getting Involved with Mathematical Music Theory. *J. Math. Music* **2014**, *8*, 167–182. [CrossRef]
34. Cslovjecsek, M.; Linneweber-Lammerskitten, H. Snappings, clappings and the representation of numbers. *N. J. Math. Teach.* **2011**, *69*, 10–12.
35. Sanders, E. Investigating the Relationship between Musical Training and Mathematical Thinking in Children. *Procedia Soc. Behav. Sci.* **2012**, *55*, 1134–1143. [CrossRef]

36. Hall, R.W. Acoustics labs for a general education math and music course. *J. Math. Music* **2014**, *8*, 125–130. [CrossRef]
37. Montiel, M.; Gómez, F. Music in the pedagogy of mathematics. *J. Math. Music* **2014**, *8*, 151–166. [CrossRef]

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.