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Development of Computational Thinking with unplugged music activities in different educational contexts

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Abstract. Working on Computational Thinking in the school environment develops specific skills such as abstraction, algorithmic thinking, automation, among others. In this field, a growing research interest relates most educational proposals to the use of technologies. This paper analyses the development of Computational Thinking through unplugged activities in the field of Music. A total of 200 primary schoolchildren, aged 10-12 years old, from public schools participated in the study. Of these, 150 were allocated to the experimental group and 50 to the control group. Data were collected before and after the intervention. The Computational Thinking Test was used to measure computational thinking. Student's t-test was used to compare possible differences between control and experimental groups. Repeated measures models were used to compare differences between pre- and post-intervention, in addition to considering moderation for different academic abilities, environment and ethno-cultural background. The results indicate that there are no mean differences at pre-test for any of the variables. After the intervention in the experimental group, the data indicate an increase in computational thinking in all students with different academic abilities, especially in the high ability group, and an outstanding development in students with learning difficulties, immigrants, and those from rural areas. The conclusions highlight the possibility of proposing educational strategies to develop computational thinking without using technology, and their effectiveness in groups with different psychosocial characteristics.
Keywords: unplugged activities; music education; student diversity; computational thinking; STEAM.

[es] Desarrollo del Pensamiento Computacional con actividades musicales desenchufadas en distintos contextos educativos

Resumen. Trabajar el Pensamiento Computacional en el entorno escolar desarrolla habilidades concretas como la abstracción, el pensamiento algorítmico, automatización, entre otros. En este ámbito, un creciente interés investigador relaciona la mayoría de propuestas educativas con el uso de tecnologías. Este trabajo analiza el desarrollo del Pensamiento Computacional a través de actividades desenchufadas dentro del Área de Música. Un total de 200 escolares de primaria, entre 10 y 12 años, de centros públicos participaron en el estudio. Entre ellos, 150 fueron asignados al grupo experimental y 50 al grupo control. Los datos fueron recogidos en tiempos pre y post- intervención. Computational Thinking Test fue utilizado para medir el Pensamiento Computacional. El test t-Student fue utilizado para comparar las posibles diferencias entre grupo control y experimental. Modelos de medidas repetidas fueron usados para comparar las diferencias entre la pre y post-intervención, además, se consideró la moderación de las distintas capacidades académicas, del entorno y del origen étnico-cultural. Los resultados indican que no hay diferencias de medias en el pretest en ninguna variable. Tras la intervención en el grupo experimental, los datos señalan un aumento del Pensamiento Computacional en todos los escolares con distintas capacidades académicas, especialmente con el grupo de altas capacidades, y, un desarrollo destacado en escolares con dificultad de aprendizaje, inmigrantes y de zonas rurales. Las conclusiones remarcan la posibilidad de plantear estrategias educativas para desarrollar el Pensamiento Computacional, sin usar las tecnologías, y su eficacia en grupos con distintas características psicosociales.
Palabras clave: actividades desenchufadas; educación musical; diversidad educativa; pensamiento computacional; STEAM.

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1. Introduction

The latest educational laws in force in Spain, specifically the Organic Law on Education, in its consolidated text LOMLOE 2020, calls for the development of computer language at all educational stages, either as specific or transversal content. Royal Decree 157/2022, which establishes the organisation and minimum teachings of Primary Education, includes, within the description of Digital Competence, the need to work on Computational Thinking throughout the entire stage and from the different areas. In addition, mathematical competence and competence in science, technology, and engineering (STEM) are included. This term is widely accepted as STEAM, since the scientific literature considers the arts as an essential part of this set (Leroy & Romero, 2021). On the other hand, in Pre-school Education, Royal Decree 95/2022, of 1 February, which establishes the organisation and minimum teaching requirements for Pre-school Education, states that, in area 2 Discovery and exploration of the environment, the skills of the scientific method and Computational Thinking will be progressively experimented with. Thus, the learning of Computational Thinking has been introduced in Infant and Primary Education classrooms, the aim being to include new electronic devices that develop pupils' digital competence, but also to develop the language of programming from childhood.

Some of the most widespread curricular proposals focus on the learning and handling of devices (Angeli & Valanides, 2020; Dittert et al., 2021) such as Bee-bot, m-bot, or blue-bot (among others), which familiarise and initiate the youngest pupils in a basic programming language. Other tools used in upper primary school are Scratch, code.org, or LEGO Mindstorms (AlQarzaie & AlEnezi, 2022; Pérez-Marín et al., 2020), which allow students to be introduced to the programming language in a playful way. All these proposals are based on the use and handling of equipment.

However, international agencies such as UNICEF report that at least two-thirds of school-aged students worldwide do not have access to the internet at home, and as a consequence, have limited electronic resources. These students belong to vulnerable and rural contexts. Therefore, from an educational perspective, the variety of contexts must be taken into account, and the availability of resources is not always equitable in all learning centres. Some platforms such as Programamos.es and CSUnplugged take into account these possible factors, and therefore have a repository of activities called "unplugged" or "disconnected" (Bell et al., 2009). These activities allow for the development of computational thinking without the need for electronic devices, seeking inclusive education and equal opportunities for all.

Given the new educational demands, the absence of a specific area in Primary Education to work on computer sciences, and the possible needs of educational contexts, this work presents the design and application of the training program "Unplugged Music," which develops computational thinking from the area of music without using devices.

2. Literature Review

Computational Thinking is defined by Wing (2017) as "the thought processes involved in forming a problem and expressing its solution(s) in such a way that a computer, human or machine, can carry it out effectively" (p. 8). The development of computational thinking is widely attributed to the use of electronic devices or computer programs, usually used in areas such as Computer Science, Technology or Mathematics.

However, the characteristics of the area of Music, and its intrinsic relationship with the field of science (Bell & Bell, 2018), offer a variety of possibilities for working on content related to Computer Science. In the literature, Collins (2018) details the relationship between algorithmic thinking and musical composition from the earliest historical-musical clues (such as, for example, Pythagorean tuning). In relation to the present day, learning experiences are being published such as those of Baraté et al. (2019), who work on programming through building blocks, using musical language as a basis, or the work of Andreoti &Frans (2019) who describe STEAM (Science, Technology, Engineering, Arts and Mathematics) pedagogy through the European project iMuSciCA and how it allows students to consolidate concepts about physics.

Working with Computational Thinking in the classroom leads to the development of specific skills. These skills vary from author to author, with more or less extensive classifications. Bocconi et al. (2016), in their work, summarise the most accepted classifications into five specific ones:

- Abstraction: making a problem more understandable by reducing unnecessary details.
- Algorithmic thinking: arriving at a solution to a problem through a clear definition of the steps.
- Automation: the process of saving work by performing repetitive tasks.
- Decomposition: thinking in parts and components to solve complex problems.
- Debugging: analysis and evaluation to predict and verify an outcome.

– Generalisation: identifying patterns, similarities, and relationships.

These skills can be developed in a variety of disciplines and are not exclusive to computing. For example, they are already being worked on in music so that students can understand a musical text. For example, there are experiences that involve working with abstraction, decomposition, and algorithmic thinking in musical composition, with positive data in both computational learning and music theory (Shafer & Skripchuk, 2020). The literature shows how research is being done to make computers capable of finding patterns and understanding musical structures, as performed by music students and professional musicians (Giraud et al., 2016) to streamline musical study processes, as well as musical composition and analysis.

In addition to the skills outlined above, there is evidence that working on computational thinking enables the development of other skills. Klein & Lewandowski-Cox (2019) highlight the development of employability-related skills, such as new media literacy and adaptive thinking, which consists of the ability to set realistic and concrete goals in different situations, generating emotions in line with the experiences.

Going back to the basis of this work, the "Unplugged Music" training programme, as mentioned above, is oriented towards working with computing through activities that do not require the use of computers. Bocconi et al. (2016) stress that Computational Thinking is a thinking process and can therefore be worked on independently of technology. Unplugged activities, to be called as such, must meet the premises of the work of Bell et al. (2009): they must be designed to encourage problem solving, use low-cost materials and be adaptable to a variety of educational contexts.

Current data show that there are results on the improvement of computational skills through unplugged training programmes (Relkin et al., 2021) and that working through unplugged activities has brought computational thinking closer to children and adolescents in schools with few resources (Branco et al., 2021). The need to look for alternatives for computer education in rural areas is latent, as the digital divide is becoming increasingly visible between urban and rural scenarios, and some research on incoming university students shows this (Clark, 2020; Nunez et al., 2020). Studies such as Simmonds et al. (2019) call for teacher training through computer-based workshops to update methodologies, with unplugged activities as one of the fundamental pillars.

The "Unplugged Music" training programme proposes activities based on active methodologies, with a particular emphasis on cooperative work that seeks the participation of all students. This approach proposes a school working environment that promotes interpersonal relationships and is adapted to the demands and challenges of today's society (Juárez-Pulido et al., 2019).

Following these recent lines of educational innovation in the development of device-free computational thinking, the general aim of this research is to test the impact of the 'Unplugged Music' programme on computational thinking. From this, the following specific aims are derived:

– To design and apply the musical training programme 'Unplugged Music'.
– To find out the general impact of the programme on students in the third cycle of primary education.
– To analyse the development of computational thinking considering its context (urban or rural).
– To study the development of computational thinking according to the characteristics of the pupils (academic ability and cultural diversity).

3. Methodology

3.1. Methodological approach

This study is developed through a quasi-experimental design, with pre-test and post-test measures in two groups. These groups are the experimental group, whose members take part in the musical computational thinking training programme, and the control group, made up of subjects who do not take part in the training activities.

3.2. Variables

The dependent variable of the study is the improvement of students' Computational Thinking. The independent variable in this case would be the use or not of the Unplugged Music programme. In addition, the following controlled variables have been considered for the analysis of the experimental group:

– Setting: Pupils in the rural group are defined as those belonging to population groups of less than five thousand inhabitants, whose educational centre has one teaching line or even multilevel classrooms. The urban group refers to those belonging to municipalities with more than 5,000 inhabitants and a variety of services, whose educational centre has at least one complete teaching line.
– Academic ability: This classification considers the educational data of the student population. A group with learning difficulties is defined as schoolers who need support in the classroom, have a curricular adjustment in at least one area or are following a special programme. A gifted or high-ability student is defined as a

student who has at least one curricular enrichment programme. The middle group refers to pupils who follow the school curriculum without any of the above adaptations. These adaptations are made by the school through the educational agents and protocols established to improve the teaching-learning process of the students, independently of this study.

- Cultural diversity: It is understood as culturally diverse students who have a nationality other than Spanish.

3.3. Population and Sample

The sample was selected by convenience, with students from centres whose specialist music teachers agreed to perform the unplugged music activities in the music sessions and those whose legal guardians gave express consent for data collection participating in the sample. In addition, they had to meet the following criteria:

– Belong to public schools in Andalusia (Spain).
– Be in the third cycle of Primary Education (5th or 6th grade) in the school year 2020/2021 and have acquired basic musical knowledge up to those corresponding to 4th grade of Primary Education (fluent reading of simple scores in treble clef, identification of the figures presents in these scores such as different rhythmic figurations, repetition bars, identification of measures, etc.).
– Do not belong to centres that provide training in robotics, either in school or out of school. Nor have any previous knowledge of programming.

Having established these criteria, 200 primary schoolchildren aged 10 to 12 years (46% girls, age *M* = 11.06, *SD* = 1.00) participated in the study. An experimental group (N =150, 45.3% girls, age *M* = 11.08, *SD* = 1.00) and a control group (N=50, 48% girls; age *M* = 11.00, *SD* = 1.00) were formed.

The characteristics of the participants in the experimental group were as follows:

– Context: Rural (9%) and urban (91%).
– Academic abilities: Medium group (82%), learning difficulties (14.7%), talents and high abilities (3.3%).
– Ethnic-social characteristics: No (86%), Yes (14%). Those who do present these characteristics have Chinese (0.67%), Venezuelan (2.67%), Italian (0.67%), Moroccan (1.33%), Georgian (1.33%), American (0.67%), Costa Rican (0.67%), Dutch (0.67%), Ecuadorian (2%), Brazilian (0.67%), Turkish (0.67%) and Gypsy (2%) nationalities.

3.4. Instruments

To obtain data from the students, they completed a short questionnaire at the time of the pre-test and post-test in which they indicated their gender, age, year, and nationality. This questionnaire had a personal identification number so that the specialist teachers could later identify and provide information on academic ability.

To evaluate Computational Thinking, the *Computational Thinking Test Scale* was used, α =.793 (Román-González, 2015). This scale is composed of 28 questions that evaluate different behaviours, with multi-option answers in which only one of them is correct. The reliability indexes were optimal in pre-test Ω=.95, and post-test Ω =.957.

Each of the questions of the scale is encompassed in one or more of the following dimensions:

– Computational concept addressed:
  o Directions: Item works directional cues, e.g., "turn right" (4 items).
  o Loops (repeat "times", repeat until): The items possess repetition cues, such as "repeat twice, move forward", or "move forward until you reach…" (4 items).

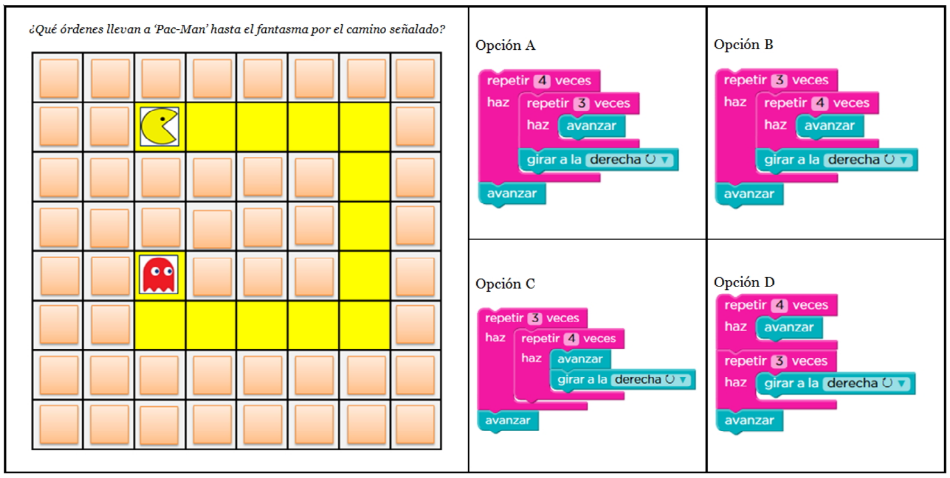

Figure 1. Example of a question with loop concept (Román-González, 2015).

- o Conditionals (simple, compound, "while"): Items have directions such as "if I pass by…", "if there is road ahead make forward, if not, make turn right", "as long as there is road ahead make forward" (4 items).
- o Simple functions: group several instructions under the same name (4 items).
- – Item environment: Maze (23 items) and canvas (5 items).

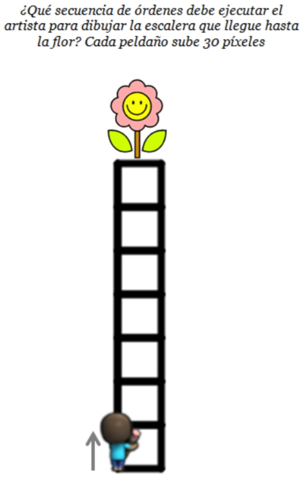

Figure 2. Example of a question with canvas environment (Román-González, 2015).

Figure 3. Examen of a question with maze environment (Román-González, 2015).

- – Response style: Visual by arrows (8 items) and visual by blocks (20 items).

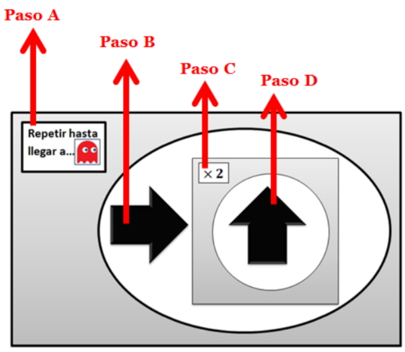

Figure 4. Example of a question with visual arrows response style (Román-González, 2015).

Figure 5. Example of a question with visual blocks response style (Román-González, 2015).

- – Existence or not of nesting: if there are instructions that derive from another instruction (with nesting we have 19 items, and without nesting we have 9 items).

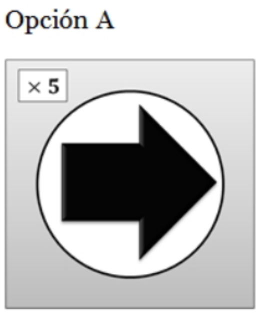

Figure 6. Example of question without nesting (Román-González, 2015).

Figure 7. Example of question with nesting (Román-González, 2015).

- – Task required: Sequencing (ordering steps, 14 items), completion (completing steps, 9 items), debugging (checking steps to identify an error, 5 items).

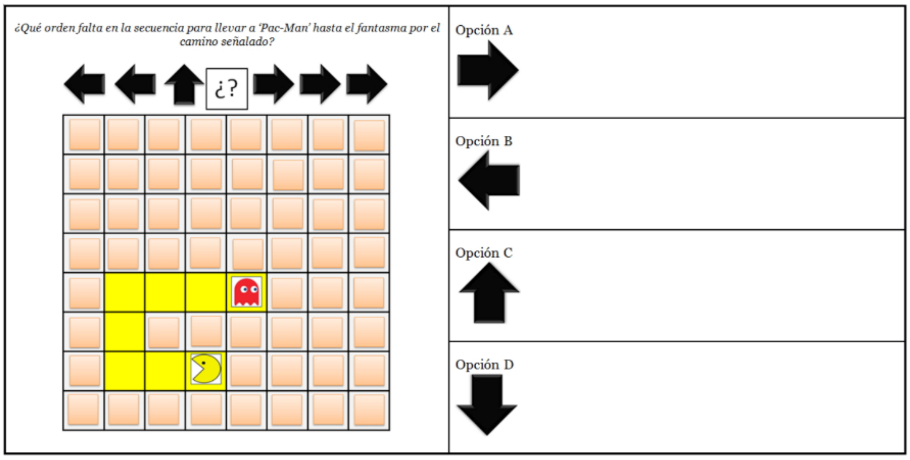

Figure 8. Example of question with completion (Román-González, 2015).

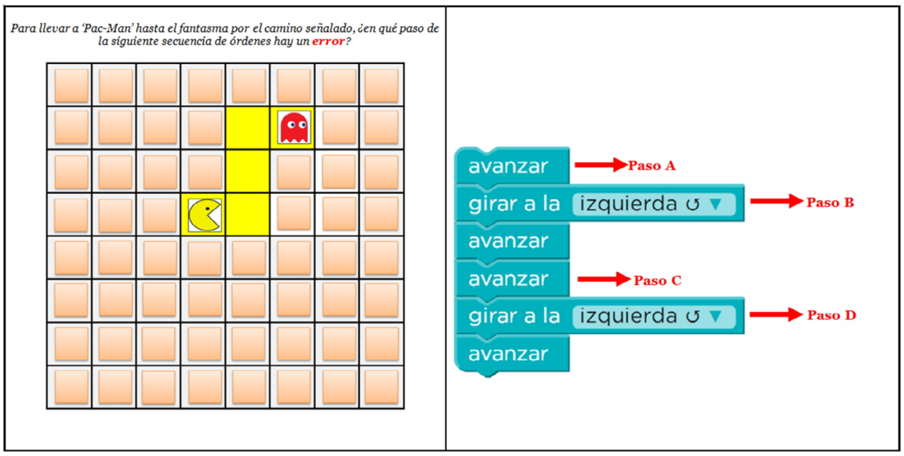

Figure 9. Example of question with debugging (Román, 2015).

3.5. Data collection and analysis procedure

3.5.1. Procedure

Sampling was incidental by accessibility. Schools and teachers were contacted to request their collaboration. Those who agreed were contacted to establish the intervention schedule shown in Table 1. The questionnaires were administered by trained researchers. Before administering the questionnaire, permission was requested from the students' families; anonymity, data confidentiality and the voluntary nature of the questionnaire were emphasised, and the student could withdraw from the program or from the questionnaires at any time. To carry out the intervention, the researchers trained the teachers on how to solve the tasks and worked together with the students in the development of the sessions.

Table 1. Schedule of actions

Group	Actions		
Experimental	Pretest (April)	Implementation of the training program "Unplugged Music". (April- June)	Pos-test (June)
Control	Pretest (April)		Pos-test (June)

First, the initial measurement (pre-test) was performed: the students of the experimental and control groups solved the questions of the Computational Thinking Test without specific training.

After the first collection, the musical training program focused on Computational Thinking was carried out in the experimental group. As classroom planning, the teachers carried out the following actions: each session counted with explanation time, and after this, the students worked in cooperative groups. These groups were made up of the following roles, which rotated during each training session:

– Spokesperson: Communicates the results elaborated by the group.
– Secretary: Transcribes what the group is solving, with indications from the other members.
– Moderator: Establishes turns to speak, maintains an appropriate tone of voice in the group.
– Supervisor: Checks if the task is being carried out according to what the group indicates, controls that all members of the group participate in the task.

The program consists of four tasks of progressive difficulty, both in musical content and in the dimensions addressed. Three forty-five minutes sessions were necessary for each task. These tasks are carried out through different boards of squares, which contain fragments of sheet music that are out of order. The students must write the necessary commands to order the score, for which they are provided with a model score, and the resolution of the board was combined with practical activities related to the score: listening to the score, music grams, score analysis, instrumental practice of the piece (boom whackers, plates, and small school percussion), explanation and recognition of musical spellings.

In the first task, a simple melodic line, in 4/4 time, of the song "*Just Give Me a Reason*", by the musical group Pink, is worked on. In this activity the students have to recompose the score through directions with arrows, using loops and simple nesting. The type of task is specifically the maze type, and the task of the students is to write the necessary commands to complete the score.

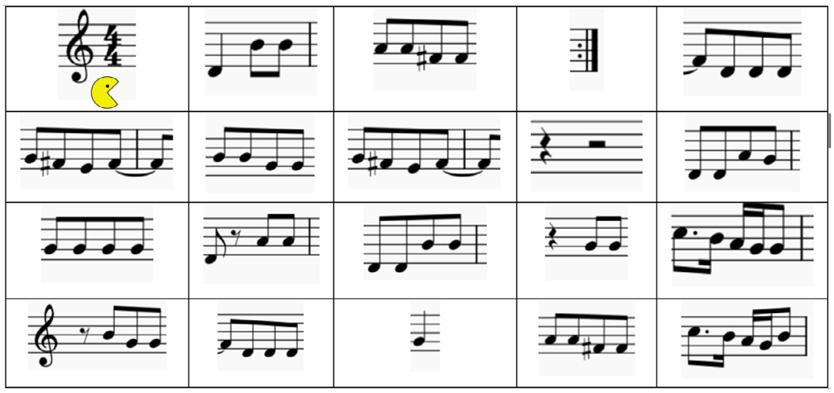

Figure 10. First task board

Figure 11. Score of the first task

The second task has a score in question-answer form on two staves, written in 4/4, with repeat signs, an accidental alteration, and indications of character and agogics. The score is an adaptation of the jazz theme "*Autumn Leaves*". In this task they have to recompose the score using block indications, with simple loops and nesting, working the canvas environment (although visually the environment is labyrinthine, the indications to order the score are in "pixels", typical of the canvas environment. Thus, the students were told that each square was 60 pixels on a side).

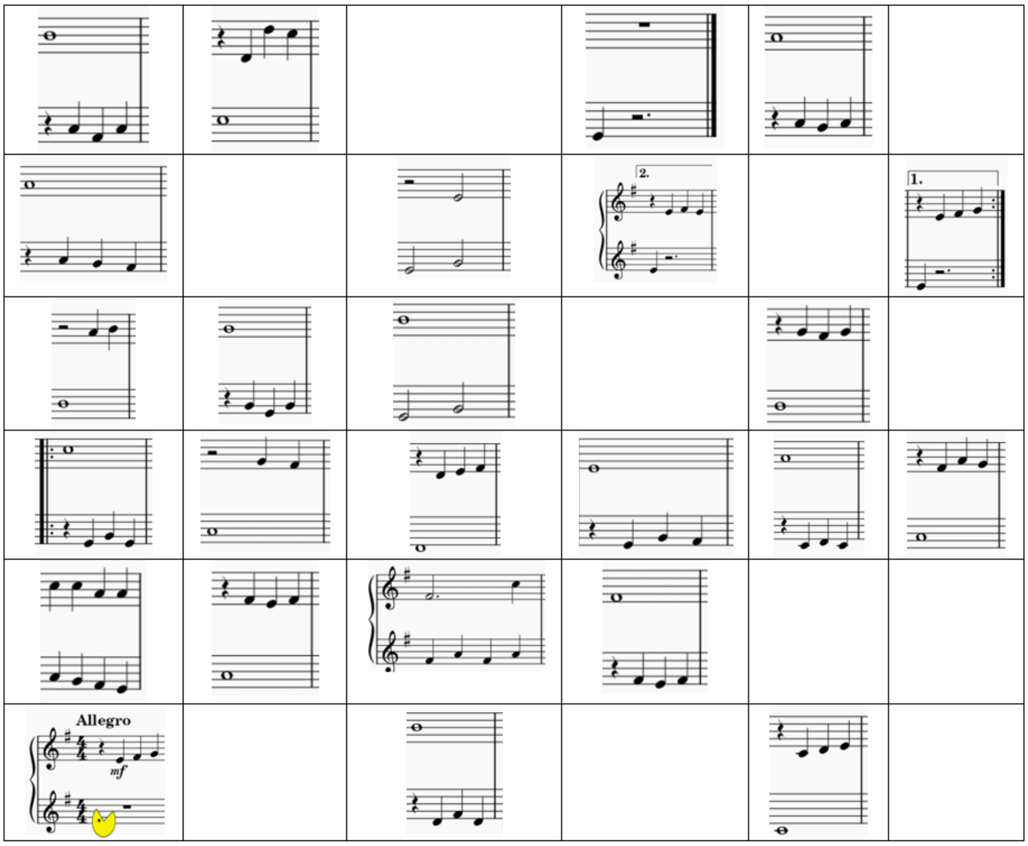

Figure 12. Second task board

Figura 13. Score of second task

The third task is based on a score of Vivaldi's "*Autumn*". It is a score written on two staves, with a polyphonic character, written in 4/4, with an accidental alteration, repeat signs and dynamics. To recompose it, it is necessary to make use of block indications, conditionals, "repeat x times" loops and simple nesting in the labyrinth environment.

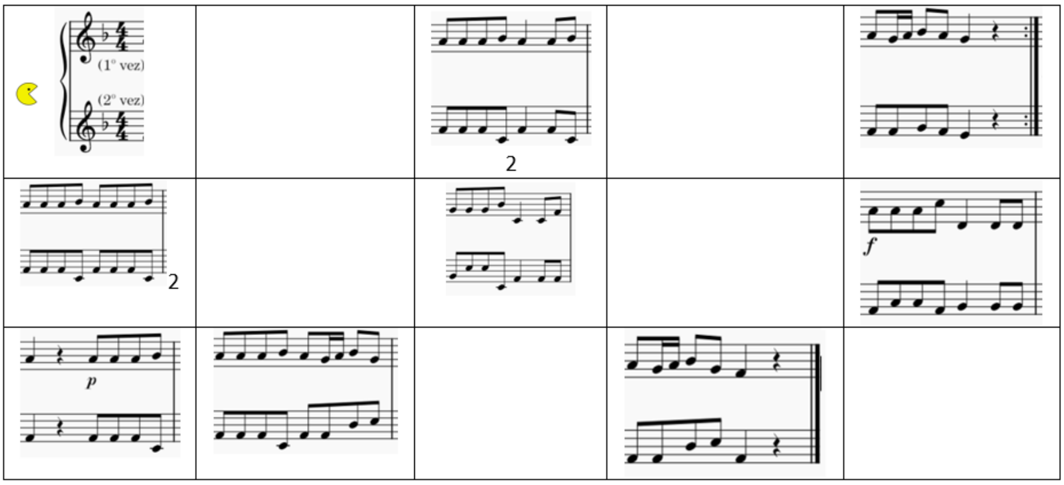

Figura 14. Third task board

Figure 15. Score of third task

The fourth and last task is worked on through the score "We are the World", written on two staves, the upper one being the melodic line of the voice, accompanied by the lyrics. The lower stave refers to a simple instrumental accompaniment. It is written in 4/4, with agogic and dynamic indications, signs and boxes for repetition and figuration with the use of dotted notes and counterpoints. This task works on block indications, conditionals, functions, and nesting in a canvas (it was performed as in task number two).

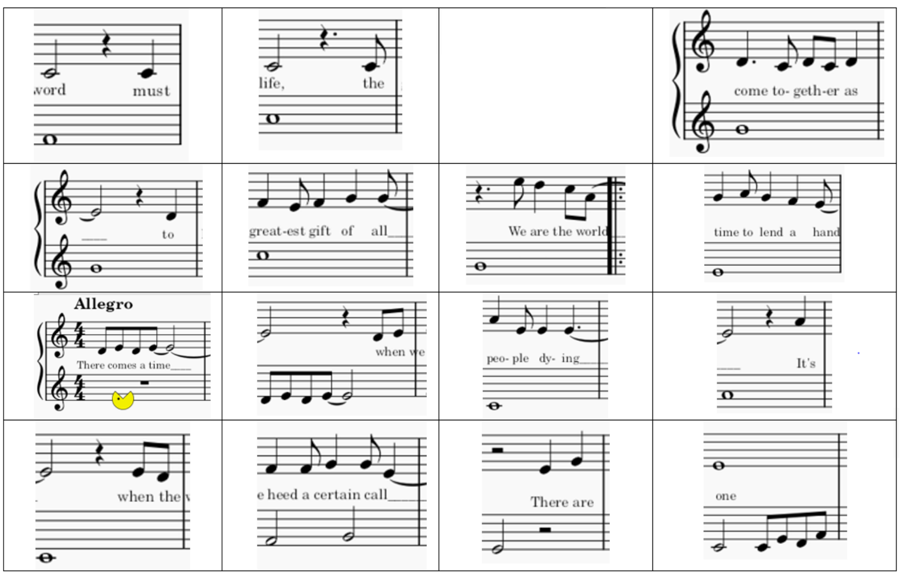

Figure 16. Fourth task board

Figure 17. Score of fourth task

After completing the training program, an evaluation test (post-test) of Computational Thinking was applied to both the experimental group and the control group.

These work sessions with the experimental group were carried out during the third quarter of the 2020/2021 academic year, within the artistic education (music) sessions of the students' regular schedule. The training sessions were carried out according to the recommendations of the music education specialist teachers, who supervised the activities developed.

3.5.2. Data analysis

In terms of data analysis, to achieve the proposed objective, the different dimensions were created using the mean scores in general and in each of the dimensions that make up the Computational Thinking questionnaire described above.

To compare the possible differences in the means between the control and experimental groups, the student's t test for independent samples was used as a pre- and post-test. Subsequently, the effectiveness of the training programme was examined using repeated measures linear models, comparing the pre-test and post-test in both the experimental and control groups, considering the variables of environment, academic ability, and cultural diversity. Tukey's test was used for post hoc analysis. Data coding and analysis were carried out using the SPSS version 26 statistical package.

4. Results

4.1. Impact of the 'Unplugged Music' programme on computational thinking in third grade students

The results concerning the impact of the "Unplugged Music" training program on the prevalence of computational thinking showed different percentage variations in the experimental group but not in the control. Thus, the Chi test was significant in the experimental group for Computational Thinking Test, $\alpha = .793$; $\chi 2(361,150) = 557.481$; $p = .000$.

Possible differences in means between experimental and control groups were analysed using Student's t-test for independent samples (Table 2).

Table 2. Analysis of mean differences between the experimental and control groups

	M	SD	T	p
Pre-intervention, computational thinking experimental group	11.83	3.95	-.629	.530
Pre-intervention, computational thinking control group	12.20	4.80		
Post-intervention, computational thinking experimental group	17.86	4.55	7.472	.000
Post-intervention, computational thinking control group	12.26	4.70		

Mean differences between the control and experimental groups, and in the pre-test and post-test were analysed using Student's t-test for repeated samples. Specifically, computational thinking and the factors included in it were analysed.

In relation to the differences in the pre-test and post-test, in the experimental group, computational thinking (t = -18.30; p =.000), and most of the constructs that compose it were variables that increased more than in the control group after the application of the music training program (Table 3).

Table 3. Pre-test and post-test scores for Computational Thinking, as well as for its component constructs

		Experimental Group (N = 150)			Control Group (N=50)		
		M	SD	p	M	SD	p
F1	Pre- intervention	11.83	3.95	.000	12.20	4.80	.000
	Post-intervention	17.86	4.55		12.26	4.70	
F2	Pre- intervention	10.48	3.56	.000	10.46	4.08	
	Post-intervention	14.76	3.82		10.34	3.97	
F3	Pre- intervention	1.44	1.01	.897	1.42	.90	
	Post-intervention	3.13	1.27		1.44	.90	
F4	Pre- intervention	5.42	1.84	.000	5.38	1.99	
	Post-intervention	6.53	1.42		5.32	2.00	
F5	Pre- intervention	6.51	3.06	.000	6.50	3.20	
	Post-intervention	11.36	3.74		6.50	3.15	
F6	Pre- intervention	11.83	3.95	.000	12.26	4.70	
	Post-intervention	17.86	4.55		12.24	4.71	
F7	Pre- intervention	5.45	2.19	.000	5.42	2.35	
	Post-intervention	8.90	2.60		5.46	2.35	
F8	Pre- intervention	5.00	2.24	.000	4.82	2.44	
	Post-intervention	7.61	2.51		4.82	2.47	
F9	Pre- intervention	2.14	1.41	.000	2.38	1.74	
	Post-intervention	2.87	1.44		2.42	1.69	
F10	Pre- intervention	1.38	1.16	.003	1.26	1.12	
	Post-intervention	2.20	1.26		1.36	1.19	
F11	Pre- intervention	1.01	.88	.160	1.10	.95	
	Post-intervention	1.72	1.01		1.20	1.01	
F12	Pre- intervention	1.72	1.06	.000	1.88	1.27	
	Post-intervention	2.46	1.09		2.02	1.30	
F13	Pre- intervention	6.15	2.13	.000	5.86	2.09	
	Post-intervention	9.26	2.60		5.82	2.06	
F14	Pre- intervention	4.20	1.79	.000	4.58	2.00	
	Post-intervention	5.66	1.78		4.60	1.87	
F15	Pre- intervention	1.57	1.09	.080	1.44	1.12	
	Post-intervention	2.96	1.14		1.42	1.01	
F16	Pre- intervention	7.03	3.01	.000	7.04	3.62	
	Post-intervention	11.65	3.68		7.08	3.53	

Note. F1= Factor 1, computational thinking; F2 = Factor 2; maze environment, F3= Factor 3, canvas environment; F4 = Factor 4, visual style response by arrows; F5 = Factor 5, visual style response by blocks; F6 = Factor 6, direction concept; F7 = Factor 7, "repeat x times" loop concept, F8 = Factor 8, "repeat until" loop concept, F9= Factor 9, simple conditional concept; F10= Factor 10, compound conditional concept; F11= Factor 11, "while" conditional concept; F12= Factor 12, simple function concept; F13= Factor 13, sequencing task; F14= Factor 14, completion task; F15= Factor 15, debugging task; F16= Factor 16, nesting.

4.2. Impact on computational thinking in groups from different backgrounds

Considering the interaction of the environment variable, rural (9%) and urban (91%), the affectivity of the program was evaluated. The results show significant statistical differences ($F = 6.223$; $p = .014$) that show an increase in means in urban and rural schoolchildren. However, in the present study it should be noted that the increase in means is more pronounced in the rural environment (Figure 18).

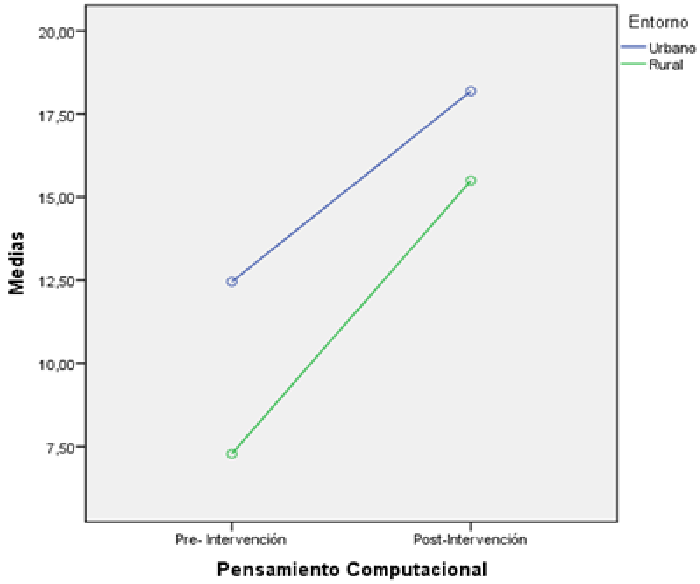

Figure 18. Scores of the experimental group in groups of different environments.

4.3. Supplementary data: Impact on computational thinking in groups with other characteristics

4.3.1. Different academic capacities

The effectiveness of the program was analysed considering different academic abilities of the students. The mean differences relative to the pre- and post-intervention, in the experimental group, indicated that computational thinking ($F = 6.844$; $p = .001$) increased significantly in all groups with different abilities more than in the control group after the intervention (Figure 19).

Significant differences were found in the post hoc analysis between the following groups: in the high ability group compared to the standard group ($p = .006$) and to the learning-disabled group ($p = .001$) with higher means in the high ability group.

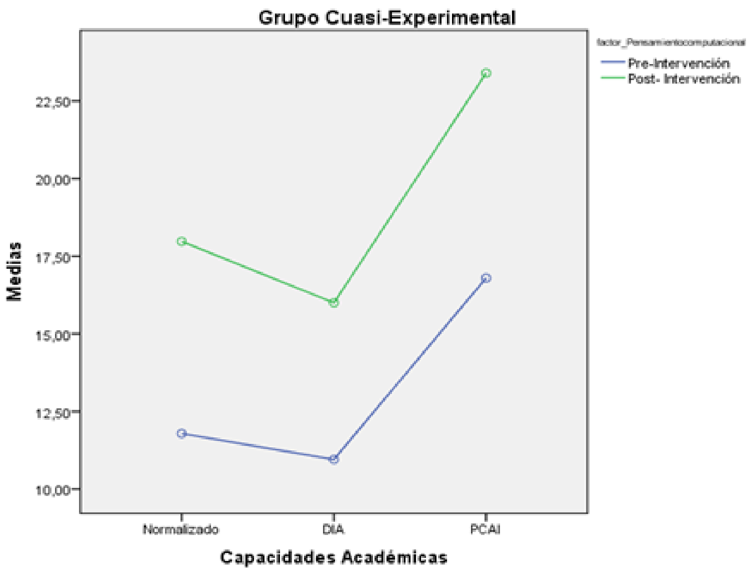

Figure 19. Experimental group score in the different academic ability group

4.3.2. Cultural Diversity

Considering the interaction of the ethno-social origin variable (native and foreign), the effectiveness of the programme was assessed. The results show significant statistical differences ($F = 6.109$; $p = .015$) indicating a greater increase in mean scores for both groups, with the increase in mean scores being slightly greater for students of native origin (Figure 20).

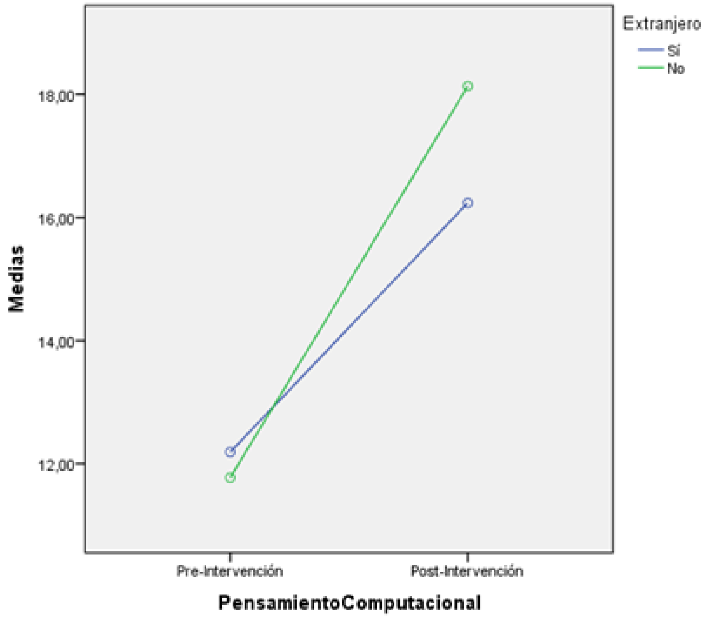

Figure 20. Experimental group score in the cultural diversity group

5. Discussion and conclusions

Most of the research on the development of Computational Thinking, as well as those training interventions in this aspect, are usually aimed at the use of electronic devices. In this aspect, regarding the general objective proposed in this work, to test the impact of the "Unplugged Music" programme on Computational Thinking, it must be said that the results have been satisfactory, observing a positive development in the scores of the participating students.

With regard to the sample, the number of subjects who participated in it is considered to be a limitation. In this aspect, the control group, which would have been of interest to be of the same size as the experimental group, is mentioned in particular.

The instrument used to determine the impact of the training programme was the Computational Thinking Test (Román-González, 2015). This has been used in other studies, such as those of Álvarez-Rodríguez (2017), who used it effectively to test the development of Computational Thinking in students in the 6th year of Primary School after training with Scratch. The test has certain limitations that the author himself expresses it does not show specific items that allow us to evoke correct algorithms, or complex and open problems. However, through the activities proposed in the musical training, these aspects are worked on, although they are not evaluated as such. Therefore, and with respect to this limitation, it would be of interest to evaluate this training programme with other instruments, such as the one developed by Kong & Wang (2021) or through the Bebras problems (Lockwood & Mooney, 2018).

In relation to the specific objective of *designing and implementing the Unplugged Music education programme*, it is concluded that the premises of the so-called Unplugged Activities were fulfilled throughout the proposed tasks. These premises were

- Encourage problem solving: In this case it is done through cooperative solving on the computer board.
- Use inexpensive materials: In the proposed activities, only pencil and paper are needed, as the board can be printed or made by hand.
- Adaptability to a variety of contexts: The activities can be modified to suit the tastes and interests of the participating students. In addition, the above premise of using low-cost materials allows them to be carried out in different settings, regardless of the level of resources available to the educational centre.

Experience shows good results when performing unplugged computational tasks, such as those presented in this study, as activities preceding the study of programming basics, as well as improving the logical-mathematical reasoning of these students (Montes-León, et al., 2020). On the basis of these data, we conclude that the data obtained, and the effectiveness of the unplugged musical activities proposed with the aim of developing computational thinking are positive.

In relation to the specific objective of *finding out the impact of the programme in general on pupils in the third cycle of primary education*, the general results show a significant increase in the experimental group in most of the dimensions measured after the training programme. These results are particularly noteworthy as they are in line with previous scientific literature. Studies have observed how solving unplugged activities improves computational thinking skills, regardless of the learning background of the study group (Sun, et al., 2021).

Regarding the specific objective of analysing the development of computational thinking considering its context (academic skills and cultural diversity), it is worth mentioning that the students belonging to the urban group stand out in the study, but nevertheless the development of computational thinking is more pronounced in the rural group. As a limitation, it should be noted that the representation of this group in this study is low, so it would be interesting to extend the study to a larger number of the population. Part of the difficulty in finding participants from rural areas stems from the situation of the specialist music teacher, as not all rural schools have this profile. This happens when an educational centre has few pupils, and the teaching staff is reduced.

On the other hand, it is necessary to contrast the data obtained on rural schools with other similar studies. Rural schools have characteristics that make it possible to provide a more personalised education: a smaller pupil/teacher ratio, resulting in greater attention from the teacher, and an environment that is familiar with cooperative and collaborative methodologies due to the existence of multi-grade classrooms. In this respect, the apparent disadvantages that are often present in rural schools make them ideal characteristics for the development of learning (Quilez-Serrano & Vázquez-Recio, 2012). Most studies on computational thinking and rural schools focus on bringing computing devices and media to these areas (Coenraad et al., 2021; Croff, 2017; Nogueria et al., 2021). There are positive data in the literature that are consistent with those found in this study, such as the development of Computational Thinking in rural students after unplugged activities (Yuliana, et al., 2021), and studies such as Avery & Kassam's (2011) that show data on how computing activities related to rural students' daily lives, in this case in the area of music, allow them to learn concepts about these sciences.

On this basis, it is concluded that the Unplugged Music training programme is suitable for the rural context in two ways. Firstly, because of its ability to develop computational thinking in students. Secondly, because it allows for a more complete musical education in those centres where there is no music specialist.

The last specific objective, which *examines the development of computational thinking according to the characteristics of the pupils*, also highlights favourable data. On the one hand, an improvement in computational thinking can be observed in all academic ability groups, with higher scores among pupils with high intellectual ability. We should bear in mind that the Unplugged Music activities are problem-solving oriented, a type of activity that is attractive to more advanced students as it allows them to practice more complex cognitive processes and to foster relationships with the rest of the students. The literature shows that incorporating unplugged activities into lesson planning means greater inclusion of this type of student in the classroom (Jagust et al., 2018). In addition, the novel complexity of these activities makes them more interested not only in the activity, but also in the subject in which it is presented. Previous research has shown that all students who engaged in computational thinking in relation to music increased their scores in music and programming, with higher grades being strengthened (Petrie, 2001). Therefore, the high scores of this group can be justified, in addition to a greater intellectual capacity, by the motivation generated towards the training programme, both at the level of designing activities and at the level of the methodology for solving them.

On the other hand, the most remarkable aspect of the data in this section is the capacity for improvement of the group of students with learning difficulties. This is justified, as in the group with higher academic ability, by the motivation shown towards novel activities and the opportunity to build social relationships based on learning. The difficulties encountered by the students in solving the activities were mitigated by the cooperative methodology (Pérez-Sánchez & Poveda-Serra, 2008), with the more advantaged students being a pillar for the students with more difficulties. For students with learning difficulties, carrying out activities based on the development of Computational Thinking, such as the training programme presented in this study, allows for the improvement of other academic aspects. Work such as that of Bouck & Yadav (2020) shows practical activities and ideas for integrating computational thinking into education with the intention of improving learning and various skills, such as mathematics, in students with learning difficulties. Other studies highlight the importance of educational innovations to bring and develop computational skills in students with learning difficulties, as currently 30% of jobs require some STEM knowledge (Israel et al., 2015). In this sense, the Unplugged Music training programme is an ally of the situation described within music education, as can be seen from the results obtained.

In terms of cultural diversity, both groups show a significant improvement in the computational thinking score, regardless of their background. Therefore, the training programme is effective in culturally diverse environments. These data are complemented by other studies, such as those by Santos et al. (2011), who have produced data showing that ethno-cultural background is not a variable that influences certain aspects of training. Furthermore, studies such as Pérez-Sánchez & Poveda-Serra (2008) confirm that the collaborative working model favours students' learning, with relevance for the adaptation of students with diversity, improving school adjustment and socio-emotional aspects.

In short, the Unplugged Music programme is established as an effective ally for the development of computational thinking in primary classrooms. Its importance in a variety of educational contexts is highlighted, regardless of the resources available to them, with those in disadvantaged and rural areas being the most notable.

As future lines of research for this work, we suggest extending the study based on the inclusion of unplugged activities in annual music education programmes. This approach is of interest in a globalised way, with learning situations linked to other areas, such as mathematics, and gives rise to an analysis of the evolution of the development of computational thinking from a broader and more continuous perspective during the school year. On the other hand, and as mentioned above, it would be necessary to assess computational thinking with other assessment tools, complementary to the one used in this study. In addition, it would be interesting to know the cognitive processes developed in the different stages of infant and primary education. Finally, an analytical study of unplugged activities, Computational Thinking and STEAM projects in art education classrooms is needed within the international scientific community.

Finally, an analytical study of unplugged activities, Computational Thinking and STEAM projects in art education classrooms is required within the international scientific literature and with reference to the new educational legal framework under construction.

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