

Research Article

Computational thinking in the curricular component of mathematics in basic education: Possibilities and challenges

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ABSTRACT

This article highlights and discusses aspects of the perceptions of a group of Mathematics teachers in Basic Education about Computational Thinking (CT) and its possibilities of working simultaneously with the curricular component of Mathematics in Basic Education. The case study was carried out through a continuing education course and focused on the application of questionnaires with open questions, as well as on reports on the inclusion of activities, by the participants, in their teaching practice during the course. The responses were analyzed from a qualitative perspective and the results highlight the predominance of lack of knowledge on the subject, especially with regard to the use of methodologies that develop computational thinking associated with specific objects of Mathematics knowledge.

Keywords: Unplugged Computing; Scratch; App Inventor; Mathematics teachers

1. INTRODUCTION

According to Barcelos and Silveira (2012) a strategy to be explored for the insertion of Computational Thinking (CT) in Basic Education should occur through pre-existing curricular components in the curriculum, such as Mathematics. Similarly, Barr and Stephenson (2011) describe a list of suggestions for inserting CT in Mathematics, Science, Social Studies, Languages and Arts. According to these authors, students should start working with problem solving, using algorithmic and computational methods and tools in Elementary and High School. On the other hand, there is a lack of studies relating CT to Mathematics in experiences that address teacher training. Barcelos, Muñoz, Villarroel and Silveira (2018), in a systematic review of the literature on works that present didactic activities developing CT and Mathematics competences, abilities or contents, including studies published between 2006 and 2015, only found five works, in a universe of 59, related to teacher training. The authors also conclude that it is possible to identify advances in the availability and variety of didactic activities involving CT and Mathematics, however, there are still target audiences and mathematical skills that have been little explored by the community.

The results of the work by Barcelos, Muñoz, Villarroel and Silveira (2018) corroborate the analysis presented by Yadav, Stephenson and Hong (2017), as they highlight that little has been done to examine the instructional, curricular and pedagogical implications related to initial and continuing education of teachers, regarding the inclusion of CT in Basic Education. Considering the period from 2016 to 2021, despite the significant increase in publications related to the inclusion of CT in Basic Education, based on the literature analysis, one can still see the predominance of works from the perspective of experience involving students.

2. RESEARCH METHOD

The descriptive field research case study was carried out with a theoretical and an experimental part. The experiment took place during a continuing education course, taught by the authors themselves. The activities took place from April to December 2021, lasting 60 hours, with a total of 15 meetings. The course addressed introductory CT concepts, the use of unplugged activities (without the computer), Scratch programming and the development of applications through the App Inventor platform. All activities aimed to address objects of Mathematical knowledge simultaneously with the concepts of CT. Twenty-five Mathematics teachers from public state schools participated in the activity. The nature of this study did not allow the random selection of the sample and a control group was not used, as it is a continuing education course in which participants voluntarily adhered, classifying the present research as a quasi-experimental study.

The investigation adopted a qualitative design and data collection took place through observation, records in the logbook, recordings and images. Questionnaires with essay questions were applied to the participants before and after the intervention, making it possible to gather data related to previous knowledge and conceptions on the subject, compare its evolution and analyze aspects about the possibility of using the concepts covered in the course in the respective classes in which the participants worked.

The data collected in this study aimed to answer the following questions:

- What initial perceptions does the group of teachers have about CT and its pillars?.
- What are the challenges and/or difficulties perceived regarding the inclusion of the methodologies addressed during the course in the curricular component of Mathematics in Basic Education?.

Development of the activities

In the continuing education course, the concepts of CT were related to the objects of knowledge in Mathematics through participatory research method, with moments of reflection prevailing, in which teachers were able to express their expectations and anxieties. The schedule of activities is described in [Table 1](#).

Table 1. Schedule of course activities

Classes	Content covered	Description of activities	Time
01 and 02	Computational thinking and its use in everyday life.	Main concepts of Computational Thinking. BNCC assumptions regarding Computational Thinking. The pillars of Computational Thinking.	8 hours
03	Use of Unplugged Computing to develop Computational Thinking.	Computational thinking with unplugged activities. Activities relating the pillars of PC and Mathematics content.	8 hours
04 and 05	Scratch	Use of the Scratch programming language to approach objects of mathematical knowledge. Creating games and animations.	8 hours
06	App Inventor	Elaboration of applications using the App Inventor, associated with objects of Mathematical knowledge.	8 hours
07	Unplugged activities, Scratch and App Inventor	Individual orientations to the groups for the elaboration of the didactic sequences. Definition of the approach to be used (unplugged, Scratch or App Inventor) and the Mathematical subject to be developed.	8 hours
08	Unplugged activities, Scratch and App Inventor	Individual orientations to the groups for the execution of the didactic sequences in the classroom. Application of activities in schools.	16 hours
09	Unplugged activities, Scratch and App Inventor	Socialization reports on the implementation of didactic sequences in schools.	4 hours

After the 6th meeting, 5 working groups were formed for the effective implementation of activities in the schools. Each group was responsible for preparing and applying a didactic sequence to Basic Education students, using one or more methodologies addressed in training and associated with some content of the mathematics curricular component of the Final Years of Elementary or High School. During this period, the teachers were guided by the researchers in the elaboration and execution of the activities. The report on the application of the didactic sequence occurred in the last meeting.

3. RESULTS AND DISCUSSION

Initial perceptions about CT and its pillars

The initial questionnaire had open-ended questions, 3 of which related to the general characteristics of the teachers (school years in which they work, subjects they work in Basic Education, knowledge about programming languages) and 5 about understanding the concept of CT and its pillars. With regard to practice, 87.9% work in High School and 100% of the participants taught Mathematics.

Regarding the questions: “Do you have knowledge of any programming language that can be used in Basic Education?” 75.8% said they had no knowledge of programming languages. Of those who reported some knowledge, the programming languages mentioned were: Scratch, Logo, Python, Portugol, Pascal and Delphi.

The questions related to CT conceptions and their pillars are presented below.

Question 1: *Have you ever read or heard about the subject "computational thinking"? If you answered yes to the previous question, characterize your degree of knowledge on the subjects.* To this question, 78.8% answered affirmatively, but 42.3% characterized their level of knowledge as 1, on a scale from 1 (lowest) to 5 (highest). That is to say, despite having already heard or read about the subject, the participants still consider their knowledge of the subject to be very low.

These responses corroborate the results obtained by Reichert, Barone and Kist (2020), in which 69% of the 28 participants in a continuing education course, with teachers from a municipal education network, had already heard or read about it, but only 7% claimed to have clarity on the matter. Similarly, Pasqual Júnior and De Oliveira (2019), with the participation of 25 teachers from a city in the countryside of Rio Grande do Sul - Brazil, in a similar question, obtained as a response that 100% of the participants said they did not know the topic. One can see a popularization of the theme, mainly due to its inclusion in the National Common Curricular Base-BNCC, but the lack of deeper knowledge is still predominant, which justifies the need for continuing education courses for Basic Education teachers. In this sense, Alves et. al (2020) highlight the importance of recruiting and teaching computing to *in-service* teachers graduated in different areas.

The objective of the next questions was to analyze the conception of Mathematics teachers in relation to the pillars of CT since, mainly, the "abstraction" pillar can generate different interpretations in Mathematics and Computing. In Mathematics, "abstraction" is usually associated with abstract thinking or abstract reasoning. For Giardinetto (1999), abstract thinking should serve to give greater understanding to reality, which is never presented in its finished form, with the concrete material helping in this process. Still, according to Andriola and Cavalcante (1997) abstract reasoning is characterized by the ability to solve problems composed of abstract symbols.

Another pillar that can be characterized in Mathematics, in a very simplified way, is the "decomposition" generally associated with the decomposition of an integer into its prime factors.

Question 2: *Describe in your own words what you mean by "abstraction".* When describing their understanding of abstraction, 21 participants provided answers based on the concept of abstract thinking or reasoning. We highlighted some of them: "Development of logical and abstract reasoning in Mathematics to facilitate understanding"; "Something that cannot be explained with concepts, is not palpable, not visible"; "Something that is not physical, is not palpable, is not observable".

Only 4 responses refer to the abstraction pillar as characterized in CT, which involves filtering data and classifying it, essentially ignoring elements that are not necessary so that it can focus on those that are relevant [Brackmann, 2017]. In this sense, some of the answers presented were: "Being able to extract fundamental information from the problem"; "Technique used to remove unnecessary information from a given context, keeping only what is important"; "Filtering the main information"; "Analyzing one aspect in isolation without taking the rest into account".

A different interpretation of the abstraction pillar as presented in the CT can be observed, and the use of the concept of abstraction linked, mostly, in Mathematics education, making a counterpoint between the abstract and the concrete. (Jardinetti, 1997).

Question 3: *Describe in your own words what you understand by "pattern recognition".* In this question, all the answers presented are consistent with the pattern recognition pillar of the CT as presented by Liukas (2015). Some of them are: "The ability to interpret similar behaviors in problem solving, or even in the observation of chemical, physical, biological, economic nature phenomena etc"; "Perceiving something that is repeated, that is, that occurred in other similar situation(s)"; "Identify characteristics that are repeated in certain processes".

Question 4: *Describe in your own words what you understand by "decomposition".* It is observed, in most of the answers, consensus among the participants' understanding of the concept of decomposition as presented by Brackmann (2017). We highlighted a few answers: "Dividing something complex or large into simpler parts"; "Separating some processes into parts in order to facilitate the resolution of a problem related to that process"; "Presenting the same fact in a different, more simplified way"; "Separate a given problem into smaller parts to make its resolution easier".

One of the answers presented ("In Mathematics, every number that can be written in the form of a multiplication of prime factors") refers to the Fundamental Theorem of Arithmetic, which states that every non-zero natural number different from 1 can be decomposed into a product of prime factors, deviating from the more general concept of

decomposition as presented by Liukas (2015), who associates decomposition with the process by which problems are broken into smaller parts.

Question 5: *Describe in your own words what you understand by "algorithms".* Some answers: "A way of calculating or solving a problem using an established sequence"; "Describing step by step"; "Finite sequence of rules, reasoning or operations"; "Sequence to be followed, with a defined language". A good understanding of the algorithm pillar of the CT is observed, consistent with that presented by Liukas (2015). Furthermore, the relationship with problem solving can be seen in the responses, an aspect present in Wing's (2006) definition.

Integration of Activities in Teaching Practice

After the 6th meeting, we suggested to the participants the development and application of a didactic sequence using the activities developed in the course associated with the mathematics content of the final years of Elementary or High School. For this, 5 groups were organized, which from this moment had individual orientation. At the beginning, each group was asked to determine the contents, school year and methodology used. Table 2 presents the details of the didactic sequences organized by the groups:

Table 2. Detailing of the didactic sequences applied by the participants

Groups	Covered content(s)	School year	Methodology
01	Combinatorial Analysis (Permutation, Arrangements and Combinations).	2 ^o	App Inventor
02	Linear systems	2 ^o	App Inventor
03	1 st degree polynomial functions	1 ^o	App Inventor
04	Matrix multiplication	2 ^o	Unplugged

It is important to note that, despite being stated in the initial diagnosis that 75.8% of the participants claim not to have knowledge in programming languages, the majority opted for using the App Inventor as methodology for applying the didactic sequence. It is considered that one of the factors that led to this choice is due to the school year of teaching, since App Inventor presents a characteristic present in the daily lives of students, regarding the use of applications.

Finally, all participants concluded that the experience was rewarding, as it involved students in the activities arousing their interest and motivation, meeting the main objective of the activity with regard to the development of the concomitant CT with objects of specific knowledge. As highlighted by (Alves et. al, 2020), after conducting a course for in-service teachers of Arts, History, Geography and other areas of the final years of Elementary School, the training of teachers of other subjects is shown to be an alternative to train teachers and thus allow the use of this knowledge in an interdisciplinary way inserted in planned contents of Elementary School.

Final Perceptions on the inclusion of CT in the curriculum component

After the development of the activities, a final questionnaire of 2 questions was applied with regard to the perceptions of the participants about the inclusion of programming tools in the curricular component of Mathematics and possible difficulties during the application of the didactic sequence using the activities developed in the course.

Question 1: *What is your opinion about the introduction of programming tools in the curricular component of Mathematics in Basic Education?* Of the answers presented, only one of the participants was unfavorable: "I am not in favor, because, in my point of view, introducing programming tools in Basic Education, without increasing the student's workload at school, will bring great harm to the development of basic Math skills."

The other participants justified their answers as: "Favorable, it provides expansion of possibilities and the use of logic in practice, in addition to diversifying activities, generating greater interest," "It's interesting, but at the school where I work, the computers don't work and few students have cell phones." "I am in favor of including programming in Mathematics teaching because it makes learning more enjoyable and interesting, it also allows us to see the applicability of Mathematics teaching since is through mathematical logic that programs are created". "I am in favor of it, however training needs to be more constant and the school needs to have equipment and internet connection for this".

It can be noted from the participants' responses that a possible obstacle to the use of the tools presented during the course and the inclusion of the CT in Mathematics classes refers to the lack of infrastructure in the schools. On the other hand, the answers corroborate with Karling and Monte-Alto (2017), when analyzing an approach to teaching algebra through Bootstrap programming, which is based on the idea of teaching Mathematics through computer programming, highlighting that the use of programming associated with Mathematics concepts will only be really effective if applied in the classroom, which requires stimulating Mathematics teachers' interest in its use.

In the favorable responses, it is possible to identify a consensus with the results obtained by Lozada, Celestino and Góis (2019) who, when asking a group of Mathematics teachers in Basic Education about the importance and relevance of the Basic Programming Logic approach for Basic Education, found that most responses link the importance of basic programming logic in Basic Education to the development of logical reasoning, important in the list of mathematical skills and abilities stated in the BNCC.

Question 2: *Inform possible challenges or difficulties encountered during the application of the didactic sequence in the classroom, in the curricular component of Mathematics.* Some responses stand out: "Lack of structure at school to use activities with Scratch or App Inventor"; "Low availability of resources for the development of applications in App Inventor, such as computers, for example"; "While using App Inventor we had difficulties due to the internet connection"; "I used the App inventor, but at school we don't have adequate internet on the students' cell phones, to test the developed applications, which caused some frustration in the participants".

From the participants' point of view, the scarcity of infrastructure for the application of activities involving technological resources constitutes the main obstacle to the use of Scratch or App Inventor. In a work by Matos Filho, Da Silva and Queiroz (2008) these difficulties have already been pointed out and it seems that they still persist, even with the continuous technological advance. According to the authors, difficulties such as lack of maintenance due to the high cost, few trained teachers, no exclusive workload for laboratories, in addition to natural resistance to changes, have served as obstacles to a greater insertion of activities related to Computing in Basic Education.

Another issue pointed out by the participants refers to the insecurity of both the teacher and the students: "at the beginning of the activities I noticed a certain insecurity of some students because they did not think they were capable"; "after getting used to the tool, the students had no difficulty, but I was afraid of not knowing how to answer all the questions". It is worth highlighting an excerpt from Papert's work (1993, pp. 70), which mentions the feelings of the participants in relation to the application of activities: "teachers who give equal autonomy to their students are, in this way, declaring their belief in a theory of radically different knowledge, which requires much more effort from them and their students". Regarding the answer: "I felt that I still have difficulties in mastering the use of App Inventor, I need more contact with it and time to improve", the works by Molina and Schlemmer (2011) and Nascimento (2015) point out, among the possible causes of resistance of the use of technologies in the school context, the lack of preparation and the difficulty in using them.

4. CONCLUSION

The objective of this work was to investigate pedagogical approaches for teaching CT associated with Mathematics that can be incorporated into the teaching practice in the classroom. In this sense, two initial questions were defined: 1). What initial perceptions does the group of teachers have about the CT and its pillars?. 2). What are the challenges and/or difficulties perceived regarding the inclusion of the methodologies addressed during the course in the curricular component of Mathematics in Basic Education?. Regarding initial perceptions, although 78.8% had already read or heard about CT, 42.3% classified their level of knowledge as being very low, especially when referring to the possibility of integration in the specific curricular component. With regard to abstraction and decomposition, different interpretations can be seen in Mathematics and in the definition of the CT pillars as presented in the literature. Among the challenges and difficulties presented for the inclusion of CT in the Mathematics curricular component, despite the fact that 95% favored the introduction of programming tools, it is possible to highlight the lack of infrastructure in schools and the insecurity, both of the teacher and the students, in the use programming approaches. It should be noted that many schools still lack adequate infrastructure so that approaches involving programming tools are better able to be implemented. In addition, continuous pedagogical advice is needed so that teachers feel more confident in taking these new tools and methodologies into their school practices.

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CONFLICT OF INTEREST

There are no conflicts of interest declared by the authors.

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