

Research Article

Cite this article: Rodrigues, R. N., Costa, C., Gonçalves, S., & Martins, F. (2025). Evaluating Pre-Service Primary School Teachers' Scientific Knowledge on Computational Thinking. *Educational Process: International Journal*, 18, e2025477.
<https://doi.org/10.22521/edupij.2025.18.477>

Received May 25, 2025

Accepted August 20, 2025

Keywords: Computational thinking, training program, initial teacher training, primary school

Author for correspondence:

Rita Neves Rodrigues

✉ ritanevesrodrigues@hotmail.com

✉ Polytechnic University of Coimbra, Coimbra, Portugal; University of Trás-os-Montes and Alto Douro, Vila Real, Portugal; Research Center for Didactics and Technology in Trainer Training (CIDTFF), University of Aveiro, Aveiro, Portugal



OPEN ACCESS

© The Author(s), 2025. This is an Open Access article, distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted re-use, distribution, and reproduction, provided the original article is properly cited.

Evaluating Pre-Service Primary School Teachers' Scientific Knowledge on Computational Thinking

Rita Neves Rodrigues^{ID}, Cecília Costa^{ID}, Sofia Gonçalves^{ID},
Fernando Martins^{ID}

Abstract

Background/purpose. Computational Thinking is a content that has been integrated into primary education curricula in several countries. Its proper integration into education is not limited to its inclusion in the educational curricula, and teachers and pre-service teachers must develop the necessary knowledge to integrate it into their practices in an appropriate way. This article aims to evaluate the scientific knowledge of pre-service primary school teachers on Computational Thinking during a training program of a primary school context, through the analysis of their Levels of Knowledge and Performance on Computational Thinking across three moments (Pre-Intervention, Post-Intervention I, and Post-Intervention II) of task implementation of a 9-month training program.

Materials/methods. This is a mixed-methods study, utilizing both quantitative and qualitative methods to analyze the scientific knowledge on Computational Thinking among 19 pre-service primary school teachers (mean age of 24.47 ± 9.576) enrolled in master's programs in Portugal during the academic year 2023/2024, who constitute the sample of this study. The scientific knowledge on Computational Thinking was evaluated through participants' Levels of Knowledge and Performance, using quantitative analysis across the three moments, complemented by a qualitative component that contextualized and deepened the interpretation of the results, enabling a more comprehensive understanding of their development throughout the training program.

Results. The study results revealed statistically significant differences in the scientific knowledge on Computational Thinking of pre-service primary school teachers in terms of levels and performance on Computational Thinking, between Pre-Intervention, Post-Intervention I, and Post-Intervention II. In addition, they showed that the pre-service teachers improved their scientific knowledge throughout the implementation of the training program.

Conclusion. The principal contribution of this study lies in outlining a procedure for assessing the scientific knowledge of pre-service primary school teachers regarding Computational Thinking within the context of initial teacher training.

1. Introduction

Computational Thinking has become central in the field of education (Sukkamart et al., 2024; Sun et al., 2023). Recognizing its importance, an increasing number of countries are integrating Computational Thinking into their educational curricula, aiming to foster its development from the early years of schooling (Looi et al., 2024; Rodrigues et al., 2025).

For Computational Thinking to be effectively integrated into teaching, it is not enough to incorporate it into educational curricula; both teachers and pre-service teachers must develop the necessary knowledge and skills to foster this ability in their teaching practices (Dong et al., 2024; Yun & Crippen, 2025). Initial Teacher Training plays a crucial role in this process, as it is during this stage that pre-service teachers begin developing the knowledge essential for their future professional practice, as well as their first exposure to key teaching practices for their professional development (Gomes et al., 2023).

Among the various dimensions of knowledge to be developed during this stage of teacher education, scientific knowledge constitutes a key element in the professional development of pre-service teachers (Conceição et al., 2022; Silva, Costa, Freitas, et al., 2024). Beyond ensuring conceptual accuracy, a solid command of scientific knowledge enables a critical and informed approach to pedagogical practice, thereby supporting sustained decision-making in the classroom (Caldatto & Ribeiro, 2020). It is therefore essential that pre-service teachers possess scientific knowledge about the content they will teach, enabling them to adapt it to classroom practice (Duarte et al., 2024; Santana et al., 2020).

The need to develop specific training programs that enable pre-service teachers to acquire the necessary scientific knowledge, particularly for integrating Computational Thinking into their practices, has been widely acknowledged (Angeli, 2022; Haşlamam et al., 2024). In this regard, and in line with the recommendations outlined in the relevant literature, it is essential to design and implement training programs that respond to these demands (Dong et al., 2024; Rodrigues et al., 2024; Silva, Costa, & Martins, 2024).

Inspired by Silva, Costa, and Martins (2024) training program which focused on educational robotics, a training program was created and implemented over the course of an academic year at a university in mainland Portugal, to develop the scientific, pedagogical and didactic knowledge of pre-service teachers so that they could become proficient in selecting, adapting, and implementing tasks that integrated the development of Computational Thinking dimensions into their practices, while simultaneously promoting the learning of mathematical knowledge. Given the importance of carefully designed and sustained training programs in preparing pre-service teachers to integrate Computational Thinking into their classroom practice, it is essential to evaluate their impact on pre-service teachers' scientific knowledge (Ortuño-Meseguer & Serrano, 2024). However, there remains a limited understanding of how pre-service teachers develop their knowledge during training programs, particularly in contexts that go beyond classroom observation (Duarte et al., 2025; Zaragoza et al., 2024). This gap highlights the need for studies examining the evolution of pre-service teachers' scientific knowledge over time within extended training programs.

This article aims to evaluate the scientific knowledge of pre-service primary school teachers on Computational Thinking within the scope of a training program implementation. Therefore, the following research questions were formulated:

1. Is there a significant difference in pre-service teachers' Levels of Knowledge on Computational Thinking across the three moments of task implementation?
2. Is there a significant difference in the pre-service teachers' Performance on Computational Thinking across the three moments of task implementation?

This article contributes to overcoming the gap in the field of structured approaches for monitoring the scientific knowledge of pre-service primary school teachers on Computational Thinking in initial teacher training. It provides a type of task for evaluating the scientific knowledge of pre-service primary school teachers on Computational Thinking in a process of initial teacher training, contributing to the development of more effective training strategies in this field.

2. Literature Review

2.1. Definition and Dimensions of Computational Thinking

Computational Thinking is a component of primary education curricula in several countries, involving the development of a set of interconnected dimensions that enhance the problem-solving process (ME, 2021; Yun & Crippen, 2025). Just as there is no single unanimous definition in the numerous studies of the speciality, various dimensions associated with Computational Thinking have also been proposed (Angeli & Georgiou, 2023; Haşlamam et al., 2024). In Portugal, Computational Thinking is integrated into the mathematics curriculum as a mathematical skill incorporating five dimensions, aligned with the specialized literature (Grover & Pea, 2013; Voon et al., 2022). According to the official Portuguese curriculum (ME, 2021), Computational Thinking involves the development of abstraction, decomposition, algorithmic thinking, debugging, and pattern recognition. To this end, the five dimensions are described below, based on the definitions presented in the relevant literature.

Abstraction can be defined as the ability to identify and isolate the essential elements of a problem, ignoring irrelevant details to simplify its resolution (Peracaula-Bosch & Gonzalez-Martinez, 2022). The development of abstraction will enable the simplification of complex problems by focusing on and highlighting essential aspects, thereby making the resolution more objective (Martínez et al., 2022). Therefore, in teacher training, it is essential to implement tasks that require pre-service teachers to filter out the most important elements and organize the information to solve the task (Dong et al., 2024).

Once the essential elements of a problem have been identified, the decomposition dimension follows, which consists of breaking down the task into smaller, simpler tasks that are easier to solve (Angeli & Georgiou, 2023). Thus, the development of this dimension is evident when the ability to break down a problem into more minor, less complex problems is observed (Ye et al., 2023).

Algorithmic thinking is characterised by the ability to identify small tasks that have been solved and draw up a step-by-step procedure that can be reproduced (Zeng et al., 2023). It is possible to identify the development of algorithmic thinking when the pre-service teacher can create and describe a sequence of steps that, when followed, result in the solution to a problem (Martínez et al., 2022).

Once a proposed solution to a task has been identified, debugging involves analyzing the resolution process, identifying possible errors, and optimizing the resolution found (Haşlamam et al., 2024). Debugging can therefore be promoted and analysed during the discussion of proposed solutions, encouraging the identification of errors and the suggestion of improvements to the solutions presented (Humble & Mozellius, 2023).

Pattern recognition between the various solutions to a task will enable the identification of steps that are repeated in the solving processes and are effective, allowing them to be applied to similar tasks (Hsu & Tsai, 2024). According to Looi et al. (2024), the dimension of pattern recognition can be developed by asking students to analyze a set of data, encouraging them to identify regularities and patterns within it.

Understanding the dimensions and definition of Computational Thinking within the Portuguese educational context thus provides the basis for reflecting on their implications for teacher education, particularly on the development of the didactic knowledge in mathematics necessary for its effective integration into pedagogical practice, an aspect that remains a gap in both research and initial teacher training (Dong et al., 2024; Santos et al., 2025).

2.2. Computational Thinking in the Teacher Education Process

Initial Teacher Training plays a fundamental role in developing scientific knowledge and providing pre-service teachers with a strong theoretical and methodological foundation for a well-grounded professional practice (Peracaula-Bosch & Gonzalez-Martinez, 2022). In the field of mathematics education, teachers' knowledge should be understood in a broad and integrated way, as defined in the Conceptual Framework of the Didactic Knowledge Model for Mathematics Teachers proposed by Ponte (2012). This framework integrates various dimensions, including students' knowledge and learning processes, the curriculum's knowledge, teaching practice knowledge, and mathematics knowledge for Teaching. This final dimension is emphasized by the author as the most distinctive aspect of mathematics teachers' professional knowledge, when compared to that of teachers in other disciplines. Teachers need to know not only mathematics as a science, but also school mathematics, meaning they must understand mathematical concepts in depth in order to design effective teaching proposals (Caldatto & Ribeiro, 2020; Ponte, 2012). Developing Knowledge of Mathematics for teaching is therefore essential for pre-service teachers to make informed and appropriate didactic decisions, plan lessons effectively, anticipate difficulties, and select strategies suited to their students' needs (Branco & Ponte, 2014; Duarte et al., 2024; Santana et al., 2020).

Given the integration of Computational Thinking into the mathematics curriculum (in Portugal, ME, 2021) and its growing importance internationally, Initial Teacher Training programs must prepare pre-service teachers with both the didactic knowledge and skills required to effectively incorporate Computational Thinking into their future classroom practice (Humble & Mozelius, 2023; Santos et al., 2025). However, recent studies have revealed concerns about teachers' ability to integrate Computational Thinking into their practice, highlighting a gap in teacher training (Yun & Crippen, 2025). Ortuño Meseguer and Serrano (2024) also mention that studies are scarce in the field of teacher training, particularly those that present pedagogical approaches aimed at developing Computational Thinking in teaching and learning processes. The implementation of studies focused on promoting competencies in pre-service teachers, enabling them to integrate Computational Thinking into their future practices, could result in an improvement in their students' Computational Thinking skills (Dong et al., 2024). It is therefore essential to enhance teacher training programs to ensure that pre-service teachers possess the necessary knowledge and competencies to effectively integrate this skill into their teaching, as defined by educational curricula (Yun & Crippen, 2025).

Recent studies affirm that the practical component is essential in teacher training programs in the field of Computational Thinking, intending to prepare participants to integrate this skill into their classroom practice (Dong et al., 2024; Palop et al., 2025; Quaresma et al., 2022). To include both theoretical and practical components, interventions must be continuous and of long duration, rather than just modules of curricular units or short training actions (Rodrigues et al., 2024; Zha et al., 2020). Within the practical component, for pre-service teachers to be able to integrate Computational Thinking into their future practice, it is necessary to implement lesson planning tasks, to be able to receive feedback on the work carried out, and to reflect on it (Dong et al., 2024; Tankiz & Atman Uslu, 2023). The implementation of microteaching sessions in Initial Teacher Training programs allows pre-service teachers to experience teaching in the classroom before they start practising in their curricular practicum. It also ensures that they receive specialized guidance in planning lessons, defining learning objectives, selecting methodologies to adopt, and the materials to use, as well as

giving them the opportunity to receive feedback from both their teachers and colleagues (Karalar & Aslan Altan, 2018; Täschner et al., 2025).

Despite these contributions, the majority of these studies have not assessed the level of scientific knowledge of pre-service teachers within the framework of a long-term education program.

3. Methodology

3.1. Study Design

This study adopts a mixed-methods approach (Cohen et al., 2018), combining both quantitative and qualitative methods to analyse the Levels of Knowledge and Performance of pre-service primary school teachers on Computational Thinking. The quantitative analysis focused on identifying statistical differences in these levels across three measurement moments: before the training program (Pre-Intervention (M1)), after Phase 1 of the training program (Post-Intervention I (M2)), and after Phase 2 of the training program (Post-Intervention II (M3)). The qualitative analysis explored the content of participants' task resolutions, seeking to identify strategies and changes over time. The integration of both strands was achieved through triangulation, in which the qualitative insights were used to interpret and explain the trends and variations revealed by the quantitative results. This combination provided a richer and more contextualised understanding of the impact of the training program. The study sample consisted of 19 participants, who were pre-service teachers enrolled in curricular units relevant to the study, and thus did not constitute a randomly selected sample. Throughout the implementation of the training program, audio and photographic records, as well as all documents produced by the pre-service teachers, were collected. To analyse the participants' progress, tasks designed for this purpose were applied at the three moments M1, M2, and M3. The variety of collected data provided a more comprehensive understanding of the participants' development throughout the program.

3.2. Participants

The sample for this study consisted of 19 female participants, aged between 20 and 54 ($M = 24.47$, $SD = 9.576$). All the participants were enrolled at a university in mainland Portugal in the academic year 2023/2024. Of these, 12 were attending the Master's degree program in "Primary School Teaching and 2nd Grade School Teaching in Mathematics and Experimental Sciences". At the same time, the remaining seven were enrolled in the master's degree in "Primary School Teaching and 2nd Grade School Teaching in Portuguese and History and Geography of Portugal". As an integral part of these master's degrees, throughout the school year (the period coinciding with the implementation of the training program) the participants carried out a curricular The implementation of microteaching sessions in Initial Teacher Training programs allows pre-service teachers to experience teaching in the classroom before they start practising in their curricular practicum in a primary school, organised into groups of two and three. To ensure a training experience in line with the needs of teaching practice and to allow the planning of proposals adapted to the reality of the participants, the groups previously defined for the implementation of microteaching sessions in Initial Teacher Training programs allow pre-service teachers to experience teaching in the classroom before they start practising in their curricular practicum, which were maintained throughout the training program.

3.3. Ethical Statement

This study adhered strictly to the ethical principles outlined in the Declaration of Helsinki, prioritizing the protection of participants' rights and well-being. Prior approval was obtained from the Ethics Committee of the Polytechnic University of Coimbra (reference 101_CEIPC/2022, approved on June 24, 2022), ensuring that all procedures complied with relevant ethical regulations. Participants provided informed consent after being fully briefed on the study's purpose, the voluntary nature of

their participation, and their right to withdraw at any time without repercussions. Data confidentiality was maintained, with all information collected and securely stored in compliance with the General Data Protection Regulation (GDPR, Regulation [EU] 2016/679 of the European Parliament and the Council of 27 April). These measures underscore the study's commitment to transparency, integrity, and adherence to the highest ethical and legal standards.

3.4. Instruments

Throughout the training program, documents produced by the pre-service teachers were collected, including task resolutions, prepared plans, critical reflections, and other relevant materials. Photographic, video, and audio records were also collected and transcribed for later analysis. In the moments before the training program (M1), between Phase 1 and Phase 2 of the intervention (M2), and after the training program (M3), tasks were applied to analyse the pre-service teachers' knowledge of the dimensions of Computational Thinking and their Didactic Knowledge in Mathematics (Ponte, 2012).

Each of the tasks implemented was subdivided into two parts, with Part 1 consisting of a sequence of six tasks and Part 2 of four tasks, as shown in Table 1.


Table 1. General structure of the tasks applied at Pre-Intervention (M1), Post-Intervention I (M2), and Post-Intervention II (M3)

<u>Problem situation</u>				
<u>Part I</u>				
1. Solve the problem step by step using appropriate mathematical language. Explain your reasoning at each step of the solution using diagrams, drawings, or words, and provide a contextualized response to the problem situation.				
2. Indicate all the elements of the problem situation that you considered essential to solving the task.				
3. For each element you indicated in Task 2, describe what you must do to fulfil it.				
4. Indicate the sequence of steps you need to follow to solve the problem situation.				
5. Could there be more solutions? Check that the solutions you have found follow all the steps in the sequence you indicated in Task 3. Justify your answer.				
6. What characteristics do the solutions you found for the problem situation have in common?				
<u>Part II</u>				
Draft a lesson plan (using the lesson planning model) of a session implementing your teaching practice, within the context of your practicum class, where you integrate the given problem situation. To do this, complete the following tasks.				
1. Indicate the mathematical knowledge that students need to have to solve the problem situation.				
2. Define the learning objectives related to the mathematical knowledge and skills to be achieved.				
3. Indicate the necessary resources and the expected duration, and describe the assessment to be adopted for the intended session.				
4. Describe the development of the lesson using Exploratory Teaching (Canavarro et al., 2012).				
<u>Lesson Planning Model</u>				
School year		Subject area		Duration
Prior knowledge			Resources	
Theme	Topic	Subtopic	Learning objective	Competence Areas of the Student Profile
Maths theme				

Mathematical skills				
Class assessment				
Lesson phase (Time)	Description of lesson development			
Task introduction phase (__ minutes)	Lesson development			
	Promoting mathematical learning		Classroom management	
Task development phase (__ minutes)	Lesson development			
	Promoting mathematical learning		Classroom management	
Task discussion phase (__ minutes)	Lesson development			
	Promoting mathematical learning		Classroom management	
Mathematical learning systematization phase (__ minutes)	Lesson development			
	Promoting mathematical learning		Classroom management	

The main objective of Part 1 was to develop the dimensions of Computational Thinking and the dimension of Knowledge of Mathematics for Teaching (Ponte, 2012). The first task in Part 1 involved solving a problem situation aimed at primary school students, extracted or adapted from Canavarro et al. (2022). When selecting the problem situations, it was considered that they should all involve objectives from the same mathematical theme (Numbers, ME, 2021), although the concepts involved varied. Table 2 shows the problem situations present in the three tasks applied.

Table 2. Problem situations presented in the Pre-Intervention (M1), Post-Intervention I (M2), and Post-Intervention II (M3) tasks

Pre- Intervention		How many numbers can the Numi robot write?
		Numi is a robot that only writes numbers. You are going to help Numi write numbers: using the digits 1-2-5
		1. How many two-digit numbers can Numi write?

Post-Intervention I (M2)

Four numbers



I. Using the digits on the cards, write down four different numbers, considering the following conditions:

- All numbers must have four digits;
- You cannot repeat digits in the same number.
- All numbers must start with the same digit;
- At least three numbers must be even.

--	--	--	--

II. In each of the numbers written above, choose two of the digits you used and write down the value they represent in each of those numbers.

III. Sort the numbers in ascending order.

Post-Intervention II (M3)

Deci the Robot



I. Use these cards to find different numbers.

(Please note: you can swap the cards around, but you must always use all four to make up a number.)

II. How many different numbers can you write down? Present them.

The first task in Part 1 asked for problem situations to be solved, while the remaining five tasks in this part were directly related to the dimensions of Computational Thinking. Table 3 shows the tasks that make up Part 1, followed by a description of the intended purpose of each one.

Table 3. Tasks and purposes of Part 1

Tasks	Purpose
Part 1	
1. Solve the problem step by step using appropriate mathematical language. Explain your reasoning at each step of the solution using diagrams, drawings, or words, and provide a contextualized response to the problem situation.	The pre-service teacher is asked to explain, step by step, how they solved the task, using appropriate mathematical terminology. This task allows us to analyse the pre-service teacher's knowledge related to the Knowledge of Mathematics for Teaching dimension, as we want to find out if the pre-service teacher uses appropriate mathematical terminology when explaining the solution and if they understand the mathematical concepts involved in the task.
2. Indicate all the elements of the problem situation that you considered essential to solving the task.	The pre-service teacher is asked to indicate the elements needed to solve the task. This task allows us to analyse the pre-service teachers' knowledge related to the Knowledge of Mathematics for Teaching dimension, namely, whether they use abstraction to extract the essential information from a problem.
3. For each element you indicated in Task 2, describe what you must do to fulfil it.	The pre-service teacher is asked to describe the small steps they need to take to solve the problem situation, respecting the fundamental elements of the problem situation they mentioned earlier. This task makes it possible to analyse the pre-service teacher's knowledge related to the Knowledge of Mathematics for Teaching

	dimension, namely whether they can structure problem-solving in less complex steps to reduce the difficulty of the problem, using the ability to decompose.
4. Indicate the sequence of steps you need to follow to solve the problem situation.	The pre-service teacher is asked to list a sequence of procedures to follow to solve the problem situation. This task makes it possible to analyse pre-service teachers' knowledge related to the Knowledge of Mathematics for Teaching dimension, by checking whether they can develop a step-by-step procedure to solve a problem, using algorithmic thinking skills.
5. Could there be more solutions? Check that the solutions you have found follow all the steps in the sequence you indicated in Task 3. Justify your answer.	The aim is for the pre-service teacher to review their solutions and ensure that there are no additional solutions. This task enables the analysis of the pre-service teacher's knowledge related to the Knowledge of Mathematics for Teaching dimension, specifically whether they can identify and correct errors, test, refine, and optimize their solutions using the debugging dimension.
6. What characteristics do the solutions you found for the problem situation have in common?	The aim is for the pre-service teacher to identify common parts in the solutions found to the problem situation. This task makes it possible to analyse the pre-service teacher's knowledge related to the Knowledge of Mathematics for Teaching dimension, namely, whether they use pattern recognition to recognise or identify patterns in the process of solving a problem and apply those that prove to be effective in solving other similar problems.

Although only Part 1 of the tasks will be analysed in this article, the tool consists of two parts, as mentioned above. Part 2 consisted of a set of four tasks that culminated in the construction of a plan involving the problem situation from Part 1. These tasks were directly related to the dimensions of the Conceptual Framework of the Didactic Knowledge Model for Mathematics Teachers (Ponte, 2012), specifically Knowledge of the Curriculum, Knowledge of Students and Their Learning Processes, and Knowledge of Teaching Practice. Table 4 shows the tasks that make up Part 2, followed by a description of the intended purpose of each one.

Table 4. Tasks and purposes of Part 2

Tasks	Purposes
Part 2	
Assuming you want to implement a session in your teaching practice within the context of your practicum class, where you integrate the given problem situation and solve the tasks.	
1. Indicate the mathematical knowledge that students need to solve the problem situation.	The pre-service teacher is asked to mention the mathematical knowledge involved in the mathematical situation. This task allows us to analyse the pre-service teacher's knowledge related to the dimensions of Knowledge of Mathematics for Teaching, Knowledge of Students and their Learning Processes and Knowledge of the Curriculum, as we want to find out whether the pre-service teacher uses appropriate mathematical terminology (Knowledge of Mathematics for Teaching) and identifies the mathematical knowledge (Knowledge of the Curriculum) that pre-service teachers would need to have in order to solve the problem situation (Knowledge of Students and their Learning Processes).
2. Define the learning objectives related to the	The pre-service teacher is asked to identify the learning objectives related to mathematical knowledge and skills for the current school year. This task makes it possible to analyse the pre-service teacher's knowledge related to

mathematical knowledge and skills to be achieved.	the dimensions of Knowledge of Mathematics for Teaching and Knowledge of the Curriculum, since the aim is to analyse whether the pre-service teacher identifies the learning objectives that can be achieved by solving the problem situation, within the framework of the curriculum (Knowledge of the Curriculum), using appropriate mathematical terminology (Knowledge of Mathematics for Teaching).
3. Indicate the necessary resources and the expected duration and describe the assessment to be adopted for the intended session.	The aim is for the pre-service teacher to describe the resources needed to integrate this problem situation into their practice, as well as how long they would anticipate implementing it and how they would assess the students. This task makes it possible to analyse the pre-service teacher's knowledge in relation to the Knowledge of Teaching Practice dimension, since the aim is to find out whether the pre-service teacher identifies the resources that could favour learning the knowledge involved in the problem situation, whether they can predict the duration of the planned implementation and whether they are able to define a form of assessment that suits the implementation.
4. Describe the development of the lesson using Exploratory Teaching (Canavarro et al., 2012).	The aim is for the pre-service teacher to develop an outline of a session plan, integrating this problem situation into their future educational practice, and describe how it could be presented in the classroom. This task enables us to analyze the pre-service teacher's knowledge related to the dimensions of Knowledge of Mathematics for Teaching, Knowledge of Students and Their Learning Processes, Knowledge of the Curriculum, and Knowledge of Teaching Practice. Regarding Knowledge of Mathematics for Teaching, the aim is to analyse whether the pre-service teacher uses appropriate mathematical terminology when describing their proposal. For the Knowledge of Students and their Learning Processes dimension, the aim is to determine whether pre-service teachers choose strategies that facilitate learning the knowledge they aim to develop and whether they recognize the roles they should play. For the Knowledge of the Curriculum dimension, the aim is to analyze whether the pre-service teacher can define tasks within the framework of the school year's curriculum in which the intervention is to take place. The Knowledge of Teaching Practice dimension aims to analyze whether pre-service teachers can define their role as pre-service teachers and whether they choose strategies and methodologies appropriate to the planning they intend to develop.

The tasks applied at the three moments (M1, M2 and M3), as well as the tasks implemented throughout the training program, which were similar, were developed by the research group and validated by five independent researchers. The five researchers who validated the tasks are specialists in the field of Mathematics Education, working directly in Initial Teacher Training, both nationally and internationally, and have experience in mathematics didactics, particularly in the field of developing computational thinking. The validation process consisted of each expert independently reviewing all the tasks to assess their relevance, clarity, and alignment with the objectives defined for the tasks. Feedback from the researchers was collected, and adjustments were made accordingly to improve the tasks.

3.5. Pedagogical Intervention Program

The training program, implemented over the two semesters of the 2023/2024 school year, had the primary purpose of promoting the development of pre-service teachers' scientific, pedagogical, and didactic knowledge so that they would become proficient in selecting, adapting and

implementing tasks that integrate the development of Computational Thinking dimensions into their practices while simultaneously promoting the learning of mathematical knowledge. The intervention was developed as part of the Mathematics and Didactics of Mathematics curricular units in conjunction with the Educational Practice curricular unit of the master's programs "Primary School Teaching and 2nd Grade School Teaching in Mathematics and Experimental Sciences" and "Primary School Teaching and 2nd Grade School Teaching in Portuguese and History and Geography of Portugal".

Below is a short description of the training program. A more detailed description can be found in Rodrigues et al. (2025). The general structure of the intervention plan can be seen in Figure 1.

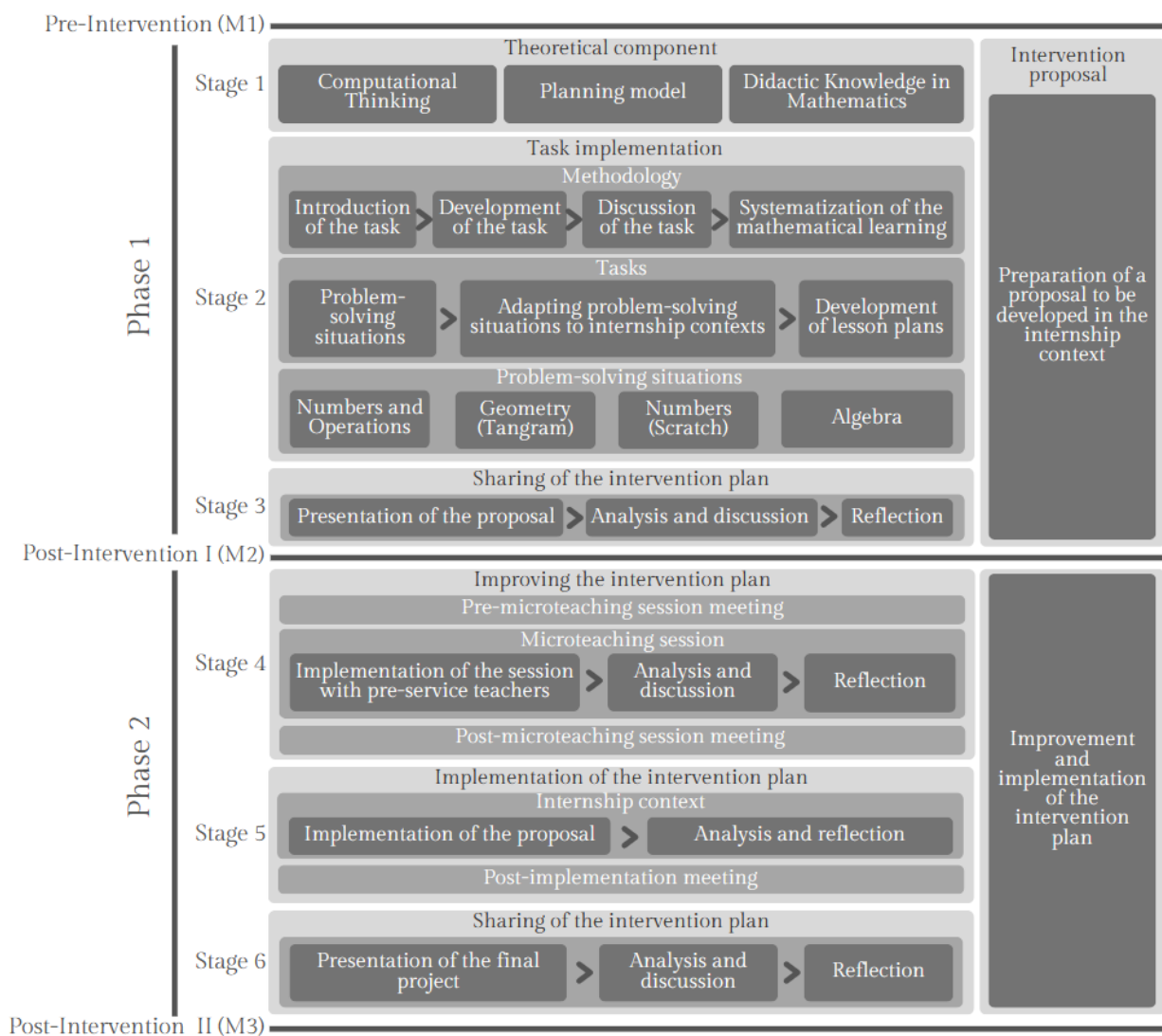


Figure 1. The general structure of the intervention plan

(Source: author's own)

The training program was developed in two phases, similar global structure to the program presented by Silva, Costa, and Martins (2024).

In Phase 1 (28 September 2023 to 6 January 2024), stages 1, 2, and 3 of the programs occurred, spread over 13 sessions, each lasting 2 hours. Stage 1 explored the theoretical concepts of Computational Thinking and the planning model to be used throughout the school year, guided by exploratory teaching practices (4-phase model) (Canavarro et al., 2012; Freitas et al., 2024). In Stage 2, each session began by solving a problem situation focused on the dimensions of Computational Thinking, followed by lesson plans involving this problem situation, exploring the appropriate

resources, learning objectives, and assessment strategies. Finally, there was a collective discussion about the knowledge needed to teach maths, according to the model of Ponte (2012). In Stage 3, each group of pre-service teachers shared an intervention plan to be implemented in their practicum, which had been constructed throughout the semester. The proposal was discussed in a large group, and feedback was given by both the researchers and their peers.

In Phase 2 (15 February to 23 May 2024), stages 4, 5, and 6 occurred, also organised in 13 2-hour sessions. In Stage 4, microteaching sessions were held where pre-service teachers implemented part of the intervention plan for the practicum with their master's degree colleagues. In these sessions, the colleagues initially played the role of Primary School students and then took part in the discussion of the proposal presented, mentioning the positive and negative aspects of the session and offering suggestions for improvement. Both before and after the microteaching sessions, the researcher met with the groups of pre-service teachers to clarify their doubts and help them prepare the tasks. Stage 5 consisted of implementing the proposals in the practicum contexts and, after each implementation, the researcher met again with each group to reflect on the intervention carried out. Finally, in Stage 6, the groups shared the results of their intervention with the others. At the end of the training program, each pre-service teacher wrote a critical reflection on the whole process.

3.6. Data collection

The collection of qualitative data occurred through individually executed tasks over the three moments (M1, M2, and M3).

The quantitative data were obtained through analysis of the tasks, and descriptors were created for the Level of Knowledge per specific objective of the tasks. Table 5 shows the criteria created for the Part 1 tasks analysed in this article.

Table 5. Levels of Knowledge descriptors by specific task objective

Tasks	Levels	Objective 1	Objective 2
1	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.
	2	Present an attempt to solve the task, but with many inaccuracies or without finalising it.	Partially describing the resolution without giving a contextualised answer to the task.
	3	Present a correct resolution to the task, with minor inaccuracies.	Write a contextualised answer to the task, without describing the other steps of the solution.
	4	Present a correct resolution to the task.	Describe the solution step by step and write a contextualised answer to the task.
2	Levels	Objective 1	
	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.	
	2	Correctly identify one of the essential elements of the problem situation.	
	3	Correctly identify most of the essential elements of the problem situation.	
3	4	Correctly identify all the essential elements of the problem situation.	
	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.	
	2	Correctly identify what you need to do to fulfil one of the essential elements of the problem situation.	

	3	Correctly identify what you need to do to fulfil most of the essential elements of the problem situation.
	4	Correctly identify what you need to do to fulfil all the essential elements of the problem situation.
4	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.
	2	Present a step-by-step procedure with the absence of essential steps for solving the task.
	3	Present a step-by-step procedure that allows the task to be solved correctly, but with some inaccuracies or including superfluous steps that do not contribute to the correct resolution.
	4	Present a step-by-step procedure to solve the task correctly.
5	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.
	2	Only mention that there are no more solutions without mentioning the verification of the solutions found with the steps defined in task 3.
	3	Mention that there are no more solutions and that the solutions found follow the steps defined, without giving a justification for each step defined in task 3.
	4	Mention that there are no more solutions and that the solutions found follow the steps defined, giving a justification for each step defined in Task 3.
6	1	Not presenting any solution or presenting an incorrect solution that is unrelated to the task.
	2	Present the characteristics common to the solutions found, but include other characteristics that are not common to all the solutions found.
	3	Present the common characteristics of the solutions found, but include other common characteristics that are superfluous in solving the problem situation.
	4	Present the common characteristics of the solutions found to the problem situation.

The evaluation of the tasks carried out at the three moments (M1, M2, and M3) made it possible to analyse the Global Level of Knowledge (GLK) and Global Performance (GP) of the pre-service teachers, based on the specific descriptors provided.

In the case of task 1 in each of the moments (M1, M2, and M3), levels were assigned to the two specific objectives defined, and the median of the levels assigned was then calculated to obtain the Level of Knowledge (LK) for task 1. To assess the GLK of the pre-service teachers at each of the three moments, a median was calculated between task 1's median and the LK of each of the remaining tasks.

To obtain the GP of each pre-service teacher, percentage values were defined for each task, and then the percentage value for each level. To obtain the GP of the pre-service teachers at each of the three moments, the percentage values obtained in each task were added together. Finally, the final values were organised into classes: [0; 25], [25; 50], [50; 75], and [75; 100].

Table 6 shows the percentage values assigned to each task and the respective levels used to obtain the GP at the three moments (M1, M2, and M3), considering that the number of objectives per task was the same and the percentage values were distributed in the same way.

Table 6. Percentage values assigned to each Level of Knowledge by task objective

Tasks	Percentage values	Levels	Objective 1	Objective 2
1	25%	1	0%	0%
		2	3%	2%
		3	11%	7%
		4	15%	10%
2	15%	1	0%	
		2	3%	
		3	11%	
		4	15%	
3	15%	1	0%	
		2	3%	
		3	11%	
		4	15%	
4	15%	1	0%	
		2	3%	
		3	11%	
		4	15%	
5	15%	1	0%	
		2	3%	
		3	11%	
		4	15%	
6	15%	1	0%	
		2	3%	
		3	11%	
		4	15%	

These criteria, like the tasks created, were also validated by five independent researchers in the field of Maths Education. Each researcher independently reviewed the criteria to ensure their alignment with the intended dimensions of Computational Thinking being assessed. Feedback was collected and discussed by the research team, leading to refinements that improved the validity and reliability of the evaluation process.

3.7. Data Analysis

3.7.1. Analysis of qualitative data

An exploratory content analysis was conducted on the qualitative data collected at three moments (M1, M2, and M3). This type of analysis involves systematically examining participants' responses to identify significant information. By doing so, it allowed the researchers to track changes in participants' resolutions over time and to identify the specific challenges they faced when completing the tasks. This analysis provided evidence of both the learning progress and the difficulties experienced by participants throughout the intervention.

3.7.2. Analysis of quantitative data

After analysing the task resolutions produced by the pre-service teachers and determining the Global Levels of Knowledge and the Global Performance at the three moments, according to the Levels of Knowledge descriptors by specific task objective (Table 5, see Subsection 3.6, Data Collection) and the Percentage values assigned to each Level of Knowledge by task objective (Table 6, see Subsection 3.6, Data Collection), the statistical analysis was conducted. Descriptive statistics were used, including relative and absolute frequency tables, to describe and compare the LK by

dimension and the GP of the pre-service teachers at the three moments when the tasks were applied. The LK and GP were characterised using frequency tables, the mean (M), and the standard deviation (SD). Levels 1 and 2 were considered to have a negative trend, and levels 3 and 4 a positive trend. Regarding the GP of pre-service teachers, the intervals [0; 25] and [25; 50] were considered negative, while the intervals [50; 75] and [75; 100] were considered positive (Freitas et al., 2024).

A one-way repeated measures ANOVA was used to compare Global Levels of Knowledge, task Performance, and Global Performance of pre-service teachers across the Pre-intervention moment, post-intervention I, and post-intervention II, after validating its assumptions (Marôco, 2021; Pallant, 2020). The assumption of normality for each dependent variable was assessed using the Shapiro-Wilk test (Marôco, 2021; Pallant, 2020). In cases where normality was not verified, symmetry analysis was performed using the following condition (Pestana & Gageiro, 2014; Tabachnick & Fidell, 2021):

$$\left| \frac{\text{skewness coefficient}}{\text{standard error of the skewness coefficient}} \right| \leq 1.96$$

The assumption of sphericity was evaluated using Mauchly's test (Pallant, 2020; Tabachnick & Fidell, 2021). If sphericity cannot be assumed, the degrees of freedom obtained by the Greenhouse-Geisser criterion should be considered for the F-statistic of the one-way repeated measures ANOVA table (Tabachnick & Fidell, 2021). The multiple comparisons of means were performed using the Bonferroni post-hoc test (Field, 2018; Pallant, 2020).

The effect size (ES) was presented as η_p^2 for the one-way repeated measures ANOVA test and interpreted using the following criteria: no effect ($ES < 0.04$), minimum effect ($0.04 \leq ES < 0.25$), moderate effect ($0.25 \leq ES < 0.64$), and strong effect ($ES \geq 0.64$) (Ferguson, 2009). Apart from ES, the power (π) of the corresponding test is also presented (Pallant, 2020).

IBM SPSS Statistics software (version 28, IBM USA) was used to perform the statistical analysis at a significance level of 5%.

4. Results

The results of the study will be presented below, subdivided by LK and GP of the pre-service teachers at Pre-Intervention (M1), Post-Intervention I (M2), and Post-Intervention II (M3).

4.1. Quantitative results

4.1.1. Levels of Knowledge

Table 7 shows the distribution of absolute and relative frequencies (%) of the pre-service teachers' LK at the three moments.

Table 7. Distribution of relative (%) and absolute frequencies of the Levels of Knowledge

	M1 (%(n))				M2 (%(n))				M3 (%(n))			
	Negative		Positive		Negative		Positive		Negative		Positive	
LK	1	2	3	4	1	2	3	4	1	2	3	4
T1	5.3(1)	10.5(2)	52.6(10)	31.06(6)	5.3(1)	5.3(1)	57.9(11)	31.06(6)	0.0(0)	0.0(0)	57.9(11)	42.1(8)
T2	47.4(9)	10.5(2)	42.1(8)	0.0(0)	26.3(5)	26.3(5)	5.3(1)	42.1(8)	0.0(0)	15.8(3)	15.8(3)	68.4(13)
T3	78.9(15)	5.3(1)	15.8(3)	0.0(0)	21.1(4)	42.1(8)	10.5(2)	26.3(5)	0.0(0)	0.0(0)	15.8(3)	84.2(16)
T4	52.6(10)	10.5(2)	21.1(4)	15.8(3)	5.3(1)	52.6(10)	26.3(5)	15.8(3)	0.0(0)	10.5(2)	5.3(1)	84.2(16)
T5	52.6(10)	26.3(5)	21.1(4)	0.0(0)	0.0(0)	42.1(8)	10.5(2)	47.4(9)	0.0(0)	42.1(8)	31.6(6)	26.3(5)
T6	63.2(12)	5.3(1)	26.3(5)	5.3(1)	5.3(1)	5.3(1)	68.4(13)	21.1(4)	5.3(1)	5.3(1)	47.4(9)	42.1(8)
GLK	57.9(11)	21.1(4)	21.1(4)	0.0(0)	0.0(0)	52.6(10)	47.4(9)	0.0(0)	0.0(0)	5.3(1)	42.1(8)	52.6(10)

Note. LK – Levels of Knowledge; GLK – Global Level of Knowledge.

Interpretation

Table 7, concerning task 1 (solve a problem situation), shows that the percentage of pre-service teachers who showed a negative trend gradually decreased, from 15.8 % in the Pre-Intervention (M1) to 10.6 % in the Post-Intervention I (M2), with no pre-service teachers showing levels of negative trend in the Post-Intervention II (M3). In task 2 (abstraction), more than 50 % of the pre-service teachers showed a negative tendency in the Pre-intervention (M1), and it is noteworthy that no pre-service teacher had a level 4 response. After the first phase of the training program (M2), there was a reduction in level 1 responses and an increase in level 4 responses. In Post-Intervention II (M3), the results showed a positive trend, with more than 80 % of pre-service teachers at levels 3 and 4. Thus, a salient result is that, after the training program (M3), 68.4% of the pre-service teachers reached level 4 in abstraction skills. Regarding task 3 (decomposition), more than 80 % of the answers in the Pre-Intervention (M1) were in the negative trend levels. In Post-Intervention I (M2), this percentage dropped to 63.2 % and was zero in Post-Intervention II (M3). It is important to note that, after the training program (M3), 84.2% of the participants reached level 4 in Task 3, which corresponds to the decomposition skills. In task 4 (algorithmic thinking), most pre-service teachers had a negative response tendency, with more than 50 % at level 1. In Post-Intervention I (M2), there was a considerable reduction in level 1 responses, although most pre-service teachers still showed a negative tendency. In Post-Intervention II (M3), there was a considerable improvement in response levels, with 89.5 % of them in the positive trend levels. Thus, it is noteworthy that, in M3, 84.2% of the pre-service teachers reached Level 4 in relation to their algorithmic thinking skills. Regarding task 5 (debugging), in the Pre-Intervention (M1), most answers, 78.9 %, were negative. Although there was a slight reduction in the percentage of level 4 answers from Post-Intervention I (M2) to Post-Intervention II (M3), the percentage of positive trend levels increased from 21.1 % in M1 to 57.9 % in the last two moments, regarding the debugging skills of the pre-service teachers. In task 6 (pattern recognition), the percentage of negative tendency responses fell from 68.5 % in Pre-Intervention I (M1) to 10.6 % in Post-Intervention I (M2) and II (M3). It should also be noted that level 4 responses doubled from Post-Intervention I (M2) to Post-Intervention II (M3), regarding skills in pattern recognition.

To better illustrate the changes over time, the progression in the Global Level of Knowledge across the three moments (M1, M2, and M3) is presented in the following graph (Figure 2).

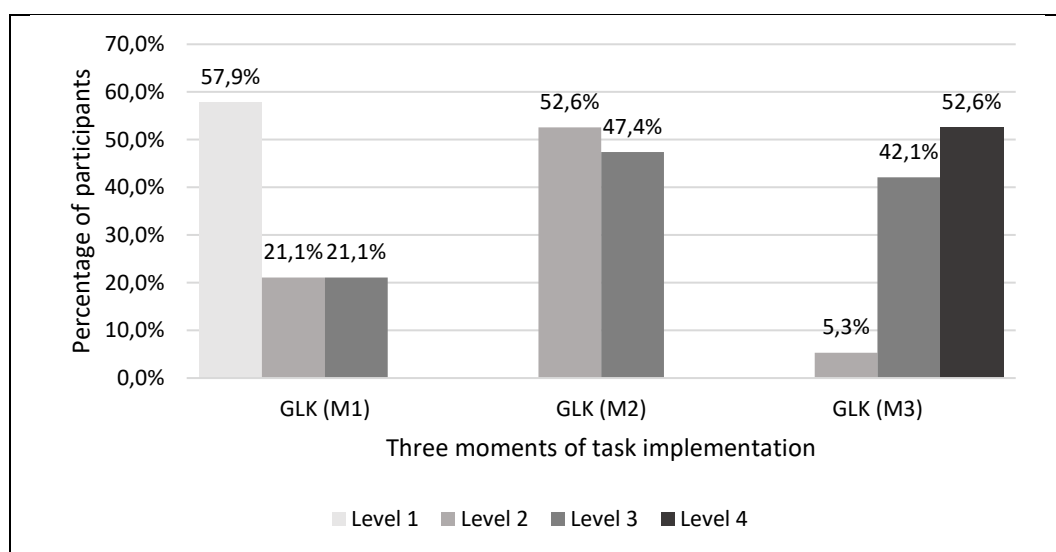


Figure 2. Global Level of Knowledge from Pre-Intervention (M1) to Post-Intervention II (M3)

Note. GLK: Global Level of Knowledge.

Regarding the GLK, 79 % of the pre-service teachers were in the negative trend levels during the Pre-Intervention (M1), with no pre-service teachers at level 4. At Post-Intervention I (M2), although there were still no pre-service teachers at level 4, the percentage of pre-service teachers at negative trend levels fell to 52.6 %, all at level 2 (10 pre-service teachers). In Post-Intervention II (M3), 94.7 % of the pre-service teachers were at the positive trend levels, with the majority at level 4 (10 pre-service teachers).

Table 8 shows the descriptive statistics and the comparison between the three moments when the tasks were applied.

Table 8. Descriptive statistics and comparison of Global Levels of Knowledge across Pre-Intervention (M1), Post-Intervention I (M2), and Post-Intervention II (M3)

M1	M2	M3	F	p	η_p^2	ES	π
1.710 ± 0.822 ^{a, b}	2.790 ± 0.673 ^{a, c}	3.579 ± 0.507 ^{b, c}	49.853	0.001	0.735	Strong Effect	1.00

Note. One-way ANOVA: significantly different at $p < 0.05$ for the following comparisons (a) Pre-Intervention vs. Post-Intervention I; (b) Pre-Intervention vs. Post-Intervention II; & (c) Post-Intervention I vs. Post-Intervention II.

Interpretation

The descriptive statistics and the comparison of GLK between the Pre, Post I and Post II moments of the intervention, shown in Table 8, suggest a significant increase in LK over the course of the intervention. The mean increased gradually over the three moments and the statistical analysis revealed a significant effect ($F = 49.853$, $p = 0.001$), with an effect size of 0.735, which indicates that the intervention had a Strong Effect on the pre-service teachers' LK. Bonferroni post-hoc comparisons indicate that the differences between Pre-Intervention (M1) and Post-Intervention I (M2), Pre-Intervention (M1) and Post-Intervention II (M3), as well as between Post-Intervention I (M2) and Post-Intervention II (M3), are statistically significant, as indicated by the comparison markers in the table. These results show that there was an overall evolution in the pre-service teachers' knowledge of Computational Thinking over the three periods analysed. In addition, the statistical power obtained ($\pi=1.00$) indicates adequate test power to detect differences between the moments.

4.1.2. Global performance

Table 9 shows the distribution of the absolute and relative frequencies of the pre-service teachers' GP at the three moments analysed. In the Pre-Intervention (M1) more than 70% of the pre-service teachers had a negative performance, with 21.1% having a performance below 25%. In Post-Intervention I (M2), no pre-service teacher performed below this value and the majority performed positively. Finally, in Post-Intervention II (M3), no pre-service teacher performed negatively, with 84.2% performing above 75 %.

Table 9. Frequency distribution of the Global Performance

Class	M1 (%(n))	M2 (%(n))	M3 (%(n))
[0; 25[21.1(4)	0.0(0)	0.0(0)
[25; 50[52.6(10)	42.1(8)	0.0(0)
[50; 75[21.1(4)	47.4(9)	15.8(3)
[75; 100]	5.3(1)	10.5(2)	84.2(16)

Table 10 shows the descriptive statistics and the comparison of the pre-service teachers' performance between the three moments analysed, by task and global.

Table 10. Descriptive statistics and comparison of Global Performance across Pre-Intervention, Post-Intervention I, and Post-Intervention II

	M1	M2	M3	F	p	η_p^2	ES	π
T1	21.515±3.312 ^a	13.524±1.560 ^{a,c}	23.158±1.642 ^c	109.499	0.001	0.859	Strong Effect	1.000
T2	4.947±5.370 ^b	7.684±6.848 ^c	13.969±1.616 ^{b,c}	18.129	0.001	0.502	Moderate effect	0.996
T3	0.195±0.369 ^{a,b}	6.3684±6.093 ^{a,c}	14.961±0.094 ^{b,c}	83.767	0.001	0.823	Strong Effect	1.000
T4	5.000±6.245 ^b	6.842±5.167 ^c	14.768±0.551 ^{b,c}	27.263	0.001	0.602	Moderate effect	1.000
T5	1.444±1.565 ^{a,b}	9.526±5.844 ^a	8.684±5.218 ^b	17.415	0.001	0.492	Moderate effect	0.998
T6	0.686±0.924 ^{a,b}	10.950±0.076 ^{a,c}	12.756±1.977 ^{b,c}	458.891	0.001	0.962	Strong Effect	1.000
GP	36.299±16.860 ^{a,b}	56.053±17.933 ^{a,c}	83.895±10.656 ^{b,c}	78.948	0.001	0.814	Strong Effect	1.000

Note. One-way ANOVA: significantly different at $p < 0.05$ for the following comparisons (a) Pre-Intervention vs. Post-Intervention I; (b) Pre-Intervention vs. Post-Intervention II; & (c) Post-Intervention I vs. Post-Intervention II.

Interpretation

The data presented in Table 10 for tasks 2, 3, 4 and 6 shows a significant increase in performance over the course of the intervention, with higher mean values in GP after each phase of the intervention. Although in task 1 there was a decrease in the mean values from Pre-intervention (M1) to post-intervention I (M2) and in task 5 a decrease from post-intervention I (M2) to post-intervention II (M3), in all tasks the mean values were always higher in post-intervention II (M3) than in Pre-intervention (M1).

The statistical analysis revealed significant differences between the moments ($p = 0.001$), with the effect size varying from moderate (between 0.492 and 0.602 for tasks 2, 4 and 5) to strong (between 0.814 and 0.962 for tasks 1, 3 and 6 and for GP), which indicates that the intervention had an effect on the pre-service teachers' Global Performance and for each of the tasks. The high statistical power values ($\pi \geq 0.996$, reaching 1.000 for most of the variables) confirm the adequacy of the test to detect differences between the moments. Regarding the Bonferroni post-hoc comparisons, Global Performance and performance in tasks 3 and 6 showed significant differences between the three moments analysed. The results for task 3 show that, over the three moments analysed, there was progress in the pre-service teachers' ability to structure the tasks into smaller, simpler tasks, showing the development of the decomposition dimension of Computational Thinking. Regarding task 6, the results obtained show that throughout the intervention there was progress in understanding the recognition and identification of patterns in the resolution processes carried out, which indicates the development of the pattern recognition dimension.

In Task 1, which always covered the mathematical topic “Numbers”, varying only in the concepts covered, there was a variation in the mean values, with a decrease at Post-Intervention I compared to the other two moments analysed. These results indicate that the pre-service teachers had some difficulties in their knowledge of the mathematical topic covered in the tasks, with the specific concepts of the Post-Intervention I task causing the most difficulties.

In tasks 2 and 4, there were significant differences between the Pre-Intervention (M1) and Post-Intervention II (M3) moments and between the Post-Intervention I (M2) and II (M3) moments, but not between the Pre-Intervention (M1) and Post-Intervention I (M2) moments. The results of task 2 indicate that, over the course of the intervention, there was an evolution in the pre-service teachers' understanding of the abstraction dimension, particularly in identifying the essential elements of the problem situations presented. Regarding task 4, the results show that there was an improvement in the ability to describe the step-by-step procedure of the solutions made, indicating the development of the algorithmic thinking dimension of Computational Thinking.

In Task 5, there were significant differences between Pre-Intervention (M1) and Post-Intervention I (M2) and between Pre-Intervention (M1) and Post-Intervention II (M3), with no significant difference between Post-Intervention I (M2) and II (M3). The results of this task show that there was an evolution in the understanding of the pre-service teachers regarding the verification and optimisation of the resolutions presented, highlighting the development of the debugging dimension of Computational Thinking.

4.2. Qualitative results

4.2.1. Pre-Intervention (Task 1)

In the resolution of task 1 presented by pre-service teacher E (Figure 3) at the time of the Pre-Intervention (M1), he was able to present the 9 possible numbers, describing how he thought step-by-step and presenting a correct answer to the problematic situation. Thus, pre-service teacher E is at level 4 according to the criteria for classifying the levels of knowledge established.

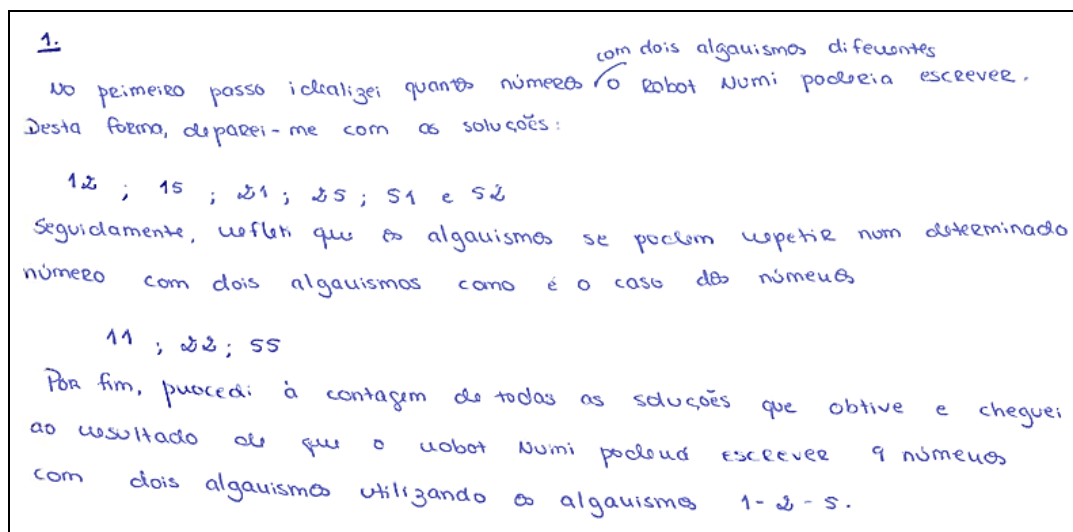


Figure 3. Pre-service teacher E's resolution for task 1 in the Pre-Intervention (M1)

(Source: author's own)

In the same task, pre-service teacher I's resolution shows that he only presented 6 of the 9 possible numbers (Figure 4). Even though he presents a contextualised response to the problematic situation, the description of the steps taken to solve it is not clear and, therefore, according to the established criteria, the pre-service teacher I is at level 3.

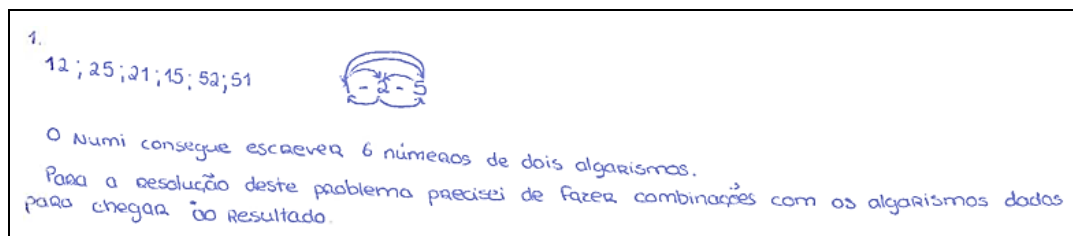


Figure 4. Pre-service teacher I's resolution for task 1 in the Pre-Intervention (M1)

(Source: author's own)

4.2.2. Post-Intervention I (Task 1)

In solving Task 1 (Figure 5), at Post-Intervention I (M2), pre-service teacher E correctly presents 4 possible numbers and sorts them in ascending order correctly. However, he doesn't give the positional value of any of the digits in the 4 numbers, he doesn't describe the solution step-by-step

or give a contextualised answer. According to the criteria defined for this task, the pre-service teacher I is at level 2.

1.

I.

<u>1</u>	<u>3</u>	<u>4</u>	<u>6</u>	(1346)
<u>1</u>	<u>4</u>	<u>3</u>	<u>6</u>	(1436)
<u>1</u>	<u>3</u>	<u>6</u>	<u>4</u>	(1364)
<u>1</u>	<u>6</u>	<u>3</u>	<u>4</u>	(1634)

II. O ~~algarismo~~ ^{algarismo} 6, nos dois primeiros números descritos representa a paridade dos números formados.

O algarismo 1, em ambos os números formados, presente na ordem das unidades de milhar, reforça o facto de os números formados terem 4 algarismos, o que não aconteceria se nesta mesma ordem estivesse presente o número 0.

III. ~~(1346) < (1436) < (1364) < (1634)~~
 $1346 < 1364 < 1436 < 1634$

Figure 5. Pre-service teacher E's resolution for task 1 in Post-Intervention I (M2)

(Source: author's own)

In the resolution prepared by pre-service teacher I (Figure 6), he correctly presented four possible numbers and the positional value of 2 digits in each number written. Although the pre-service teacher wrote the numbers in ascending order, he wrote the symbol for 'greater' instead of 'lesser'. Similarly to pre-service teacher E, pre-service teacher I did not provide a contextualised answer or a description of the steps taken. In this task, the pre-service teacher is at level 3 according to the criteria that have been defined.

1.

I. 78865
 7352
 7014
 7926

II.

7865
 5 → representa cinco unidades
 8 → representa oito centenas

7352
 5 → representa cinco dezenas
 3 → representa três centenas

7014 →
 1 → representa uma dezena
 4 → " " quatro unidades

7926
 9 → representa nove centenas
 2 → " " duas dezenas

III.

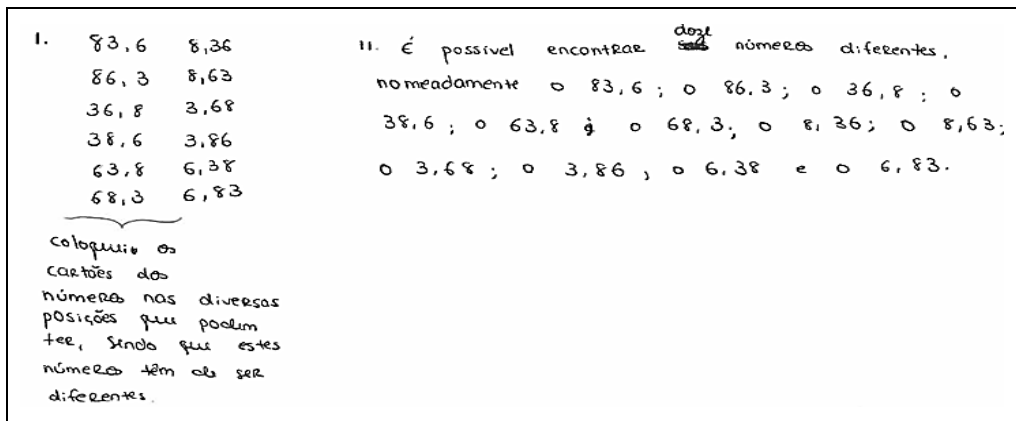
7014 < 7352 < 7865 < 7926

Figure 6. Pre-service teacher I's resolution to task 1 in Post-Intervention I (M2)

(Source: author's own)

4.2.3. Post-Intervention II (Task 1)

Regarding solving task 1 (Figure 7), at Post-Intervention II (M3), pre-service teacher E correctly presents the 12 possible numbers, describes the steps taken, and presents a contextualised response to the problem situation. Thus, the pre-service teacher is at level 4.



1. 83,6 8,36
86,3 8,63
36,8 3,68
38,6 3,86
63,8 6,38
68,3 6,83

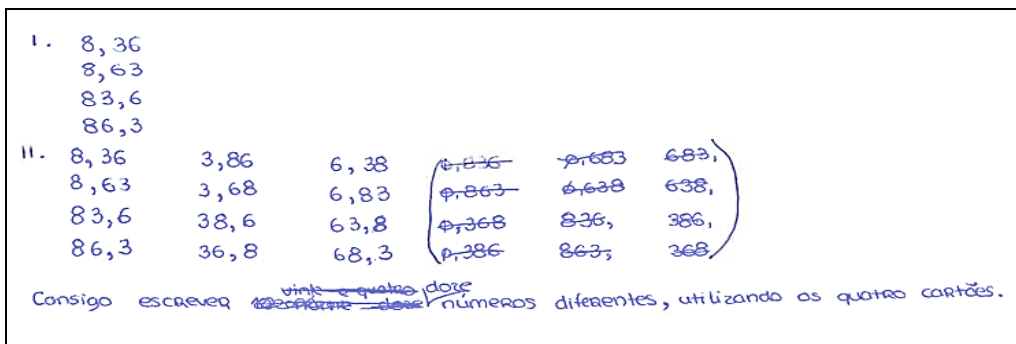
coloque os cartões dos números nas diversas posições que podem ter, sendo que estes números têm de ser diferentes.

11. É possível encontrar ~~doze~~ ^{doze} números diferentes, nomeadamente 0 83,6 ; 0 86,3 ; 0 36,8 ; 0 38,6 ; 0 63,8 ; 0 68,3 ; 0 8,36 ; 0 8,63 ; 0 3,68 ; 0 3,86 ; 0 6,38 e 0 6,83.

Figure 7. Pre-service teacher E's resolution for task 1 in Post-Intervention II (M3)

(Source: author's own)

In the resolution drawn up by pre-service teacher I (Figure 8), he presents the 12 possible numbers and answers the problematic situation, without describing the steps of the resolution. Considering the established criteria, pre-service teacher I is at level 3.



1. 8,36
8,63
83,6
86,3

11. 8,36 3,86 6,38
8,63 3,68 6,83
83,6 38,6 63,8
86,3 36,8 68,3

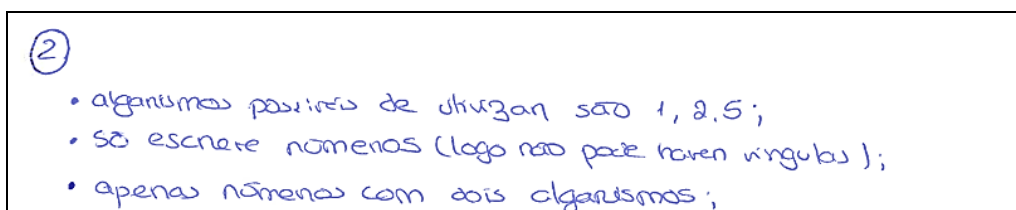
Consigno escrever ~~doze~~ ^{dois} números diferentes, utilizando as quatro cartões.

Figure 8. Pre-service teacher I's resolution to task 1 in Post-Intervention II (M3)

(Source: author's own)

4.2.4. Pre-Intervention (Tasks 2 e 3)

At the Pre-Intervention moment, pre-service teacher Q's resolution (Figure 9) shows that he was able to identify two of the essential elements for solving the problem situation (task 2) and correctly identified what he had to do to fulfil them (task 3). Given that he mentions an element that is not included in the problem situation ('only write numbers (so there can't be any commas)') and that he failed to identify one of the essential elements (the task asks how many numbers Numi can write), pre-service teacher Q is at level 3 in the two tasks analysed.



②

- alguns números possíveis de utilizar são 1, 2.5;
- só escreve números (logo não pode haver vírgulas);
- apenas números com dois algarismos;

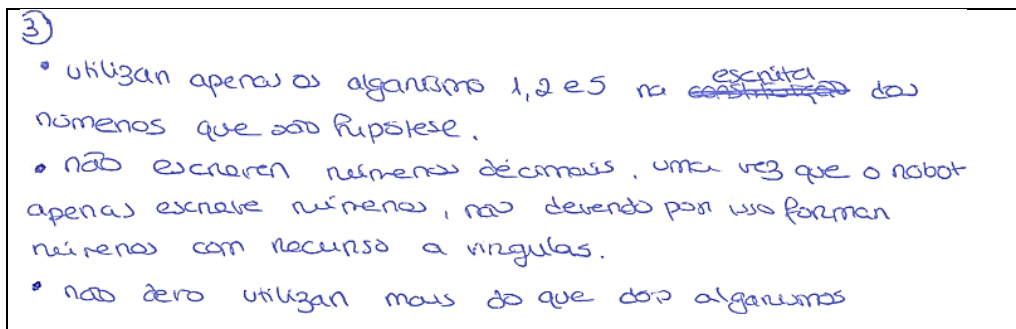


Figure 9. Pre-service teacher Q's resolution to tasks 2 and 3 in the Pre-Intervention (M1)

(Source: author's own)

At the same moment of the intervention (M1), and in relation to the two tasks analysed above, we see in the resolution presented by pre-service teacher O (Figure 10) that he did not achieve the objectives set for the tasks, not presenting any of the essential elements of the problem situation and, consequently, not identifying what he should do to fulfil them. According to the criteria established, pre-service teacher O is at level 1 in the two tasks analysed.

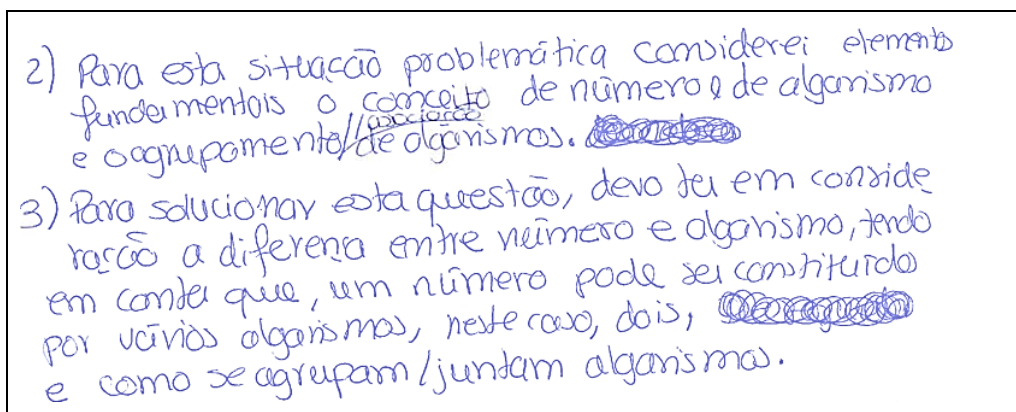
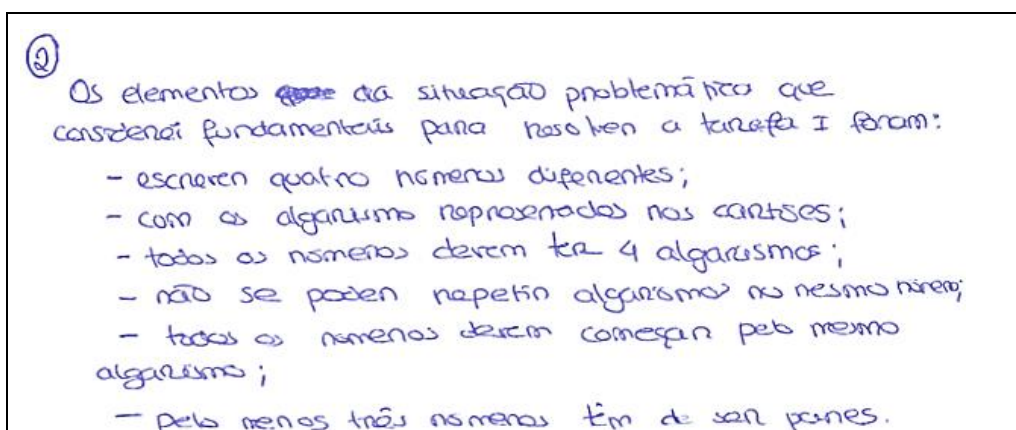


Figure 10. Pre-service teacher O's resolution for tasks 2 and 3 in the Pre-Intervention (M1)

(Source: author's own)

4.2.5. Post-Intervention I (Tasks 2 and 3)

At the moment of Post-Intervention I (M2), pre-service teacher Q (Figure 11) was able to identify essential elements for solving one of the tasks in the problem situation (task 2), correctly identifying what he had to do to fulfil them (task 3). Having not found a solution to the remaining two tasks in the problem situation, pre-service teacher Q is at level 2 of knowledge in tasks 2 and 3, according to the classification criteria that have been defined.



③ Para cumprir os elementos apresentados anteriormente devo:

- escrever quatro números diferentes utilizando os algarismos representados nos cartões, sendo que cada um dos números tem 4 algarismos
- começar os quatro números pelo mesmo algarismo e em cada um dos números não repetir algarismos.
- escrever pelo menos três números pares ou seja, escrever pelo menos 3 números em que o último algarismo seja um número par, ou seja, 0, 2, 4, 6, ou 8.

Figure 11. Pre-service teacher Q's resolution for tasks 2 and 3 in Post-Intervention I (M2)

(Source: author's own)

Regarding the resolution presented by pre-service teacher O (Figure 12), he correctly presents the essential elements to solve the three tasks in the problem situation. Thus, in task 2 of Post-Intervention I (M2), pre-service teacher O is at level 4. In the resolution presented by the pre-service teacher for task 3 (Figure 12), although he identifies what he should do to fulfil all the elements mentioned, he shows some inaccuracies (for example, in point H: 'we have to place the numbers from smallest to largest'). According to the classification criteria established for task 3, the pre-service teacher is at level 3.

2) Elementos da situação problemática que ~~devo~~ ~~considerar~~ ~~fundamentais~~ para resolver a tarefa 1:

- A) utilizar os algarismos representados nos cartões;
- B) escrever quatro números diferentes;
- C) todos devem ter quatro algarismos;
- D) não se podem repetir algarismos no mesmo número;
- E) todos os números devem começar com o mesmo algarismo;
- F) pelo menos três números têm de ser pares.
- G) ~~deve ter~~ valor que dois dos algarismos representam em cada um dos números; H) ordenar por ordem crescente.

3) A) De modo a utilizar os algarismos representados nos cartões, devemos ter em conta que, para a escrita dos números, apenas podemos utilizar: 0, 1, 2, 3, 4, 5, 6, 7, 8 e 9.

B) Para escrever quatro números diferentes, temos de ter em conta que, ao escrevermos os números, não ~~repetimos~~ ~~repetimos~~ nenhum.

C) Para todos os números terem quatro algarismos, devemos ter em consideração que o número apenas pode ser escrito até à ordem das milhares.

D) Para não se repetirem algoritmos no mesmo número, deve-se ter em conta que ~~se~~, em cada número, apenas se pode utilizar um algoritmo uma única vez.

E) De modo a todos os números começarem com o mesmo ~~algoritmo~~ ^{algoritmo}, deve-se seleccionar apenas ~~o~~ um algoritmo para ~~o~~ a ordem dos milhares de todos os números.

F) Para pelo menos três números serem pares, podemos escrever três ou mais, neste caso, no máximo quatro, que é o número solicitado, números pares. ~~estes~~
 Ordenar os três números pares.

G) ~~Para indicar o valor que dois dos algoritmos representam em cada um dos números, temos de seleccionar e verificar se pertencem à ordem dos milhares, das centenas, das dezenas ou das unidades.~~ Para indicar o valor que dois dos algoritmos representam em cada um dos números, temos de seleccionar e verificar se pertencem à ordem dos milhares, das centenas, das dezenas ou das unidades.

H) Para ordenar por ordem crescente, temos de colocar o número do mais pequeno para o maior.

Figure 12. Pre-service teacher O's resolution for tasks 2 and 3 in Post-Intervention I (M2)

(Source: author's own)

4.2.6. Post-Intervention II (Tasks 2 and 3)

At post-intervention II (M3), pre-service teacher Q correctly presents the essential elements of the problem situation, as well as what he should do to fulfil them, and is therefore at level 4 in the two tasks analysed (Figure 13).

2. Para resolver a tarefa 1, os elementos fundamentais foram:

- Cantões; ~~repetidos~~
- podemos tocar os cantões de lugar;
- tem de usar sempre os quatro na composição de um número;
- encontrar números diferentes;

3. O que devo fazer para cumprir cada um dos elementos referidos em cima é:

- devo usar apenas algoritmos / elementos que se apresentem nos cantões do enunciado da tarefa
- utilizar o mesmo cantão em locais diferentes para compor diferentes números;
- usar sempre os quatro cantões;
- registar diferentes números;

Figure 13. Pre-service teacher Q's resolution for tasks 2 and 3 in Post-Intervention II (M3)

(Source: author's own)

In the resolution made by pre-service teacher F (Figure 16), not only did he not present the step-by-step procedure for solving the task, but he also demonstrated language inaccuracies in his description (for example: 'Solve the method'). In task 4 of the Pre-Intervention (M1), according to the criteria established, pre-service teacher F is at level 1.

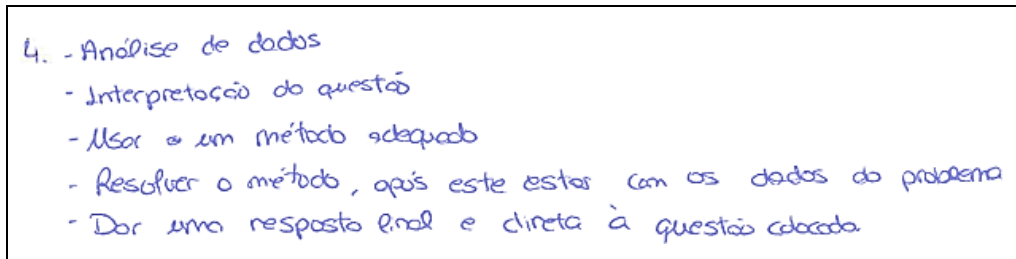


Figure 16. Pre-service teacher F's resolution for task 4 in the Pre-Intervention (M1)

(Source: author's own)

4.2.8. Post-Intervention I (Task 4)

Pre-service teacher G's resolution (Figure 17) for task 4 describes some of the steps in resolving the three tasks in the problem situation, but it has gaps in essential steps. According to the classification criteria that have been defined, pre-service teacher G is at level 2.

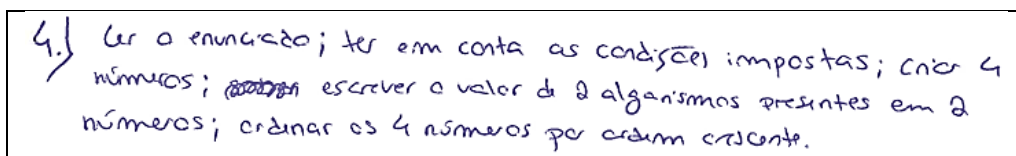


Figure 17. Pre-service teacher G's resolution for task 4 in Post-Intervention I (M2)

(Source: author's own)

In solving task 4 of Post-Intervention I (M2) (Figure 18), although pre-service teacher F mentions some of the steps in solving the three tasks in the problem situation, he doesn't present the steps that are essential for solving them. Considering the criteria defined for task 4, pre-service teacher F is at level 2.

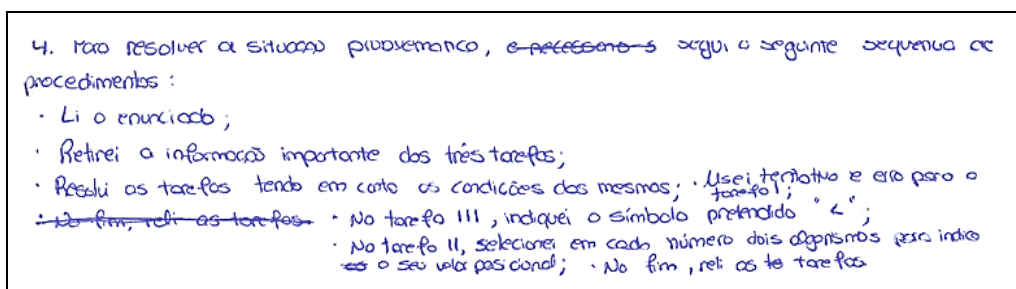


Figure 18. Pre-service teacher F's resolution for task 4 in Post-Intervention I (M2)

(Source: author's own)

4.2.9. Post-Intervention II (Task 4)

In task 4 of Post-Intervention II (M3), pre-service teacher G presents the essential steps for solving the tasks (Figure 19). As such, pre-service teacher G is at level 4, according to the classification criteria that have been defined.

4. ~~Escolher~~
 Escolher um dos cartões e ver as possibilidades que podera organizar os restantes cartões fazendo-lhes a ordem.
 Registrar todas as possibilidades.
 Verificar se não há repetições, ou seja, todos os números criados são diferentes.

Figure 19. Pre-service teacher G's resolution for task 4 in Post-Intervention II (M3)

(Source: author's own)

Regarding the resolution made by pre-service teacher F for task 4 at the time of Post-Intervention II (M3) (Figure 20), the procedure for solving the two tasks in the problem situation is correctly presented. Pre-service teacher F is therefore at level 4 according to the classification criteria that have been defined.

4) I. - Escrever os números e o vírgulo;
 - Encontrar números possíveis, trocando a posição dos integrandos todos;
 - Verificar que não há números repetidos, uma vez que têm de ser diferentes.
 II. - Encontrar todos os números possíveis diferentes, integrando os 4 cartões;
 - Verificar que não há números repetidos;
 - Contar quantos números foram encontrados;
 - Apresentar esses números.

Figure 20. Pre-service teacher F's resolution for task 4 in Post-Intervention II (M3)

(Source: author's own)

4.2.10. Pre-Intervention (Tasks 5 and 6)

At the moment of the Pre-Intervention (M1), concerning task 5 (Figure 21), although pre-service teacher C mentions that there are no more solutions and that he has fulfilled all the steps he had indicated, he doesn't provide a justification for each step. Given the criteria established for this task, the pre-service teacher is at level 3. In solving task 6 (Figure 21), pre-service teacher C does not mention the common characteristic of the solutions found and is therefore at level 1.

5) Penso que não existem mais soluções. Cumpri todos os passos que indiquei na tarefa 3. ~~Existem~~ Existem diferentes formas de obter o resultado de resposta à situação problemática, mas as conclusões serão as mesmas.
 6) As soluções que encontrei para a situação problemática seguem os mesmos passos.

Figure 21. Pre-service teacher C's resolution for tasks 5 and 6 in the Pre-Intervention (M1)

(Source: author's own)

Regarding the resolution presented by pre-service teacher M for task 5 (Figure 22), he only mentions that there can be no more solutions, without mentioning whether he followed the steps indicated in task 3. As such, the pre-service teacher is at level 2. In the resolution presented for task

6 (Figure 22), the pre-service teacher provides an incorrect answer, failing to mention the common characteristic of the solutions found. Thus, in task 6 of the Pre-Intervention (M1), pre-service teacher M is at level 1, according to the established criteria.

5. Não podem existir mais soluções, uma vez que só existem 3 possibilidades de formar números partindo dos 3 algoritmos disponibilizados. ~~e são repetidas.~~

6. A característica em comum é a propriedade combinatoria dos algoritmos.

Figure 22. Pre-service teacher M's resolution for tasks 5 and 6 in the Pre-Intervention (M1)

(Source: author's own)

4.2.11. Post-Intervention I (Tasks 5 e 6)

In Post-Intervention I, when pre-service teacher C solves task 5 (Figure 23), he correctly mentions that there could be more solutions to the tasks. However, he doesn't make the connection between the solutions he found and the steps he defined in task 3 for any of the three tasks in the problem situation. Therefore, according to the classification criteria defined, pre-service teacher C is at level 2. In the resolution presented for task 6 (Figure 23), the pre-service teacher has correctly fulfilled all the objectives set for the task and is at level 4.

⑤
R.: Podem existir mais soluções para os tarefas I, II e III.
Ao seguir todos os passos da sequência indicado na tarefa 3 é possível encontrar outras soluções para a mesma situação problemática, uma vez que existem várias combinações de algoritmos que podem ser realizadas e considerados válidos, cumprindo todas as condições apresentadas.

⑥
R.: Características em comum:
- o facto de todos os números terem quatro algoritmos, não repetindo nenhum algoritmo dentro do mesmo número, iniciando todos os números pelo mesmo algoritmo e ter pelo menos três números pares.
- o facto de o valor posicional associado a cada ordem se manter, mesmo alterando o algoritmo que se encontra nesta posição.
- o facto de, embora as números formadas possam diferir, a ordem crescente irá sempre começar com o número com menor valor e acabar com o número de maior valor.

Figure 23. Pre-service teacher C's resolution for tasks 5 and 6 in Post-Intervention I (M2)

(Source: author's own)

In the resolution drawn up by pre-service teacher M (Figure 24), he correctly justifies whether there are more solutions to each of the tasks. The pre-service teacher mentioned that he followed the steps in task 3 but didn't explain them step by step. Therefore, in task 5 of Post-Intervention I (M2), the pre-service teacher is at level 3 according to the criteria defined. Regarding task 6 (Figure 24), pre-service teacher M correctly mentions four common characteristics of the solutions found

but does not mention the common characteristics of tasks II and III. Considering the classification criteria that have been defined, pre-service teacher M is at level 3.

5. Sim, podem existir mais soluções na tarefa I, uma vez que existem dez algoritmos distintos, ou seja, existem muitas mais combinações de números para formar outros números tendo em conta os critérios ~~para~~ ~~formar~~ que indiquei na questão 3. No entanto, não existem mais soluções para as tarefas II e III, uma vez que de acordo com os números que escolhi ~~(nominalmente na II)~~ não existem outras soluções possíveis.

Sim, as soluções que encontrei seguem todas as passadas a sequência que indiquei na tarefa 3.

6. Todos os números têm quatro algarismos, três dos quatro números são pares e, todos os números começam pelo mesmo algarismo e ~~nestes~~ não existe nenhum algarismo repetido no mesmo número.

Figure 24. Pre-service teacher M's resolution for tasks 5 and 6 in Post-Intervention I (M2)

4.2.12. Post-Intervention II (Tasks 5 e 6)

In the resolution presented by pre-service teacher C for task 5 of Post-Intervention II (M3) (Figure 25), he correctly mentions that there can be no more solutions. Although the pre-service teacher mentions that he followed the steps he indicated earlier, he doesn't mention the connection between the steps he followed and the solutions he found. Therefore, the pre-service teacher is at level 3. Regarding the resolution for task 6, the pre-service teacher correctly mentions the common characteristics of the solutions recorded and is at level 4.

5) R.: Não podem existir mais soluções ~~(possíveis)~~. Seguindo os passos indicados anteriormente, foram encontrados todos os soluções possíveis.

6) R.: Têm em comum os algarismos e a vírgula presentes nos ~~(os)~~ quatro cartões utilizados para formar os números. São formados por 3 algarismos e têm casas decimais.

Figure 25. Pre-service teacher C's resolution for tasks 5 and 6 in Post-Intervention II (M3)

(Source: author's own)

In the resolution presented by pre-service teacher M for task 5 (Figure 26), he correctly mentions that there are no more solutions to the task, justifying each step he had indicated in task 3. The pre-service teacher, having started by presenting three numbers in task I, still mentions that there are more solutions for that task. The pre-service teacher is therefore at level 4. Regarding task 6, the pre-service teacher's resolution correctly presents one of the common characteristics, failing to mention the comma on the cards or the existence of decimals (as seen in pre-service teacher C's resolution). According to the classification criteria defined, pre-service teacher M is at level 3.

5. Não podem existir mais soluções para as tarefas ~~III~~ II, uma vez que seguiu todos os passos da sequência que ~~indica~~ indiquei na tarefa 3, ou seja, observei os quatro cartões para perceber quantas composições de números podia realizar, ~~mas~~ escrevi diferentes números, tocando o lugar dos cartões (a ordem) e contabilizei quantos números diferentes consegui escrever.

Relativamente à tarefa I, podem existir mais soluções, uma vez que só escrevi três exemplos de números diferentes, despendendo os passos que indiquei na tarefa 3. Ou seja, existem mais soluções na tarefa II para além das que registei.

As soluções encontradas na tarefa I e II têm características em comum, nomeadamente, o facto de ambos terem como objecto escrever números diferentes, utilizando os quatro cartões na composição dos mesmos.

Figure 26. Pre-service teacher M's resolution for tasks 5 and 6 in Post-Intervention II (M3)

(Source: author's own)

5. Discussion

By analysing the tasks applied at the Pre-Intervention moment, it was found that, before the implementation of the training program, most of the pre-service teachers had a negative performance in the execution of the tasks. These results corroborate the study carried out by Yun and Crippen (2025), who mention gaps in teacher training related to the integration of Computational Thinking. After the implementation of the training program, at Post-Intervention II, no pre-service teacher had a negative performance, with the vast majority achieving a Global Performance (GP) above 75%. These results indicate the effectiveness of the training program in promoting the development of mathematical knowledge and Computational Thinking dimensions.

Initial results revealed significant difficulties among pre-service teachers in solving the tasks, which were more pronounced at Post-Intervention I. These challenges reflect gaps in their scientific knowledge, consistent with results by Gomes et al. (2023) and Quaresma et al. (2022). For example, Task 1 responses at Post-Intervention I often omitted detailed problem-solving steps and contextualized answers, indicating a lack of recognition of the importance of these elements. However, a marked improvement was observed at Post-Intervention II after practicum planning activities, supporting the idea that sustained practical experience is crucial for developing teaching competencies (Dong et al., 2024; Palop et al., 2025). In a similar vein, the progressive improvement in abstraction skills (Task 2) aligns with Dong et al. (2024), who claim that abstraction develops during Initial Teacher Training when tasks require organizing relevant elements to plan solutions. Statistical improvements between pre- and post-intervention phases support this. These results are consistent with Tankiz and Atman Uslu (2022), who highlight the importance of lesson planning and feedback in acquiring knowledge to integrate Computational Thinking. The progressive and statistically significant improvements observed in algorithmic thinking (Task 4) align with Martínez et al. (2022), who describe this skill as the ability to define clear, step-by-step solutions. The more objective and clear solutions that emerge after Phase 2 reinforce the impact of practical components in training (Zeng et al., 2023). Improvements in decomposition (Task 3) are consistent with Ye et al. (2023), who define it as breaking complex tasks into simpler parts. The use of collaborative and exploratory teaching practices likely contributed to this development (Täschner et al., 2025).

Debugging skill improvements (Task 5) align with Humble and Mozelius (2023), who emphasize the importance of identifying errors and proposing improvements through peer critique and feedback (Haşlaman et al., 2024). Finally, the increase in pattern recognition dimension (Task 6) reflects the importance of identifying effective steps applicable in similar contexts, as noted by Hsu and Tsai (2024). The collaborative solution discussions promoted by the training program supported this skill (Looi et al., 2024).

Given the positive developments observed in all Computational Thinking dimensions, the results have important implications for curriculum design in teacher education. During both phases, mathematical topics from the Portuguese curriculum were integrated with methodologies tailored to different stages of learning. The gradual improvement from Pre- to Post-Intervention phases suggests that curriculum components should combine theoretical knowledge with sustained practical activities, particularly lesson planning and problem-solving tasks contextualised to real classroom settings. The evidence suggests the need to incorporate structured opportunities for pre-service teachers to analyze student solutions, receive targeted feedback, and reflect on their instructional approaches, thereby strengthening their didactic knowledge and preparing them to integrate Computational Thinking effectively (Karalar & Aslan Altan, 2018; Täschner et al., 2025). This two-phase model, similarly proposed by Silva, Costa, and Martins (2024), emphasizes that continuous, contextualized practice embedded in curriculum planning supports the development of both scientific and pedagogical competencies crucial for teacher readiness.

In practical terms, the study highlights key reflections regarding the integration of Computational Thinking into classroom teaching. The improvement in pre-service teachers' ability to include detailed, step-by-step problem-solving explanations and contextualization after engaging in practicum planning tasks suggests that hands-on experience with authentic teaching scenarios is essential for developing awareness of student learning processes (Ye et al., 2023). Moreover, as pre-service teachers refined their lesson plans and anticipated student difficulties, they demonstrated a better capacity to scaffold Computational Thinking skills in their future classrooms, especially in algorithmic thinking (Zeng et al., 2023) and debugging (Humble & Mozelius, 2023). The collaborative discussions of solutions further fostered pattern recognition and decomposition skills, underscoring the importance of social interaction and peer feedback in teacher development (Täschner et al., 2025). These practical experiences helped bridge the gap between theory and classroom application (Yun & Crippen, 2025), thus preparing future teachers to implement Computational Thinking as a natural and integral part of their mathematics teaching practice.

6. Conclusion

This article aims to answer the following research questions: Is there a significant difference in pre-service teachers' Levels of Knowledge on Computational Thinking across the three moments of task implementation? Is there a significant difference in the pre-service teachers' Performance on Computational Thinking across the three moments of task implementation? Considering the results presented and discussed above, there was a significant evolution in the Levels of Knowledge about Computational Thinking and the Global Performance of pre-service teachers in solving tasks involving the dimensions of Computational Thinking, throughout the three moments of the task application. There was significant progress, especially after the second phase of the training program, which reinforces the importance of a structured approach, based on active methodologies, for developing pre-service teachers' knowledge of the dimensions of Computational Thinking. Active methodologies, such as exploratory teaching practices and microteaching sessions, have proven effective in developing Computational Thinking and preparing pre-service teachers for their teaching practice. The practical experience in the practicum context proved essential for pre-service teachers to deepen their understanding of this concept and apply it more effectively in problem-solving.

The main contribution of this study is the presentation of a procedure for evaluating the scientific knowledge of pre-service primary school teachers on Computational Thinking in a process of initial teacher training. Building on this contribution, it is expected that the results of this study will contribute to the discussion on the design and implementation of specific training programs aimed at developing pre-service teachers' knowledge on Computational Thinking in initial teacher education. In this regard, the importance of training strategies that integrate theory and practice is highlighted, providing teaching experiences in practicum contexts, followed by reflection, guidance, and feedback. These strategies prepare pre-service teachers to integrate the content of Computational Thinking into teaching in a critical and informed manner.

7. Study Limitations

The results of this study showed significant evidence of pre-service teachers' development of Computational Thinking knowledge. Nevertheless, a specific limitation should be acknowledged regarding the composition of the sample, which was made up of only female participants. However, given that women predominantly attend Initial Teacher Training courses in Portugal, the sample used reflects this reality. Thus, instead of biasing the results, it guarantees their representativeness and adequacy to the characteristics of the target population.

8. Recommendations for Future Research

Considering the recognised limitation regarding the composition of the sample, future studies could expand participation to include pre-service teachers from different educational institutions and contexts, making it possible to generalise the results to other contexts.

The training program was developed based on guidelines in specialist literature and took place continuously over the course of a school year, integrating practical, theoretical, and reflective components. In this sense, a recommendation for future studies would be to conduct a longitudinal study that follows pre-service teachers after they enter the teaching profession, providing a more comprehensive view of the intervention's effects.

This study also highlights the importance of the practical experiences participants had during the practicum for the development of their knowledge of Computational Thinking, as noted in the specialized literature. Future research aims to continue analysing this component on teacher training, particularly regarding the development of pre-service teachers' professional knowledge.

Declarations

Author contributions. RNR, CC, SG & FM: resources, visualization, writing – review & editing; RNR: conceptualization, data curation, formal analysis, investigation, methodology, software, validation, writing – original draft; CC: conceptualization, data curation, supervision, validation; SG: conceptualization, methodology, supervision, writing – original draft; FM: conceptualization, data curation, formal analysis, funding acquisition, methodology, project administration, software, supervision, validation. All authors have read and approved the final version of the article.

Conflicts of interest. The authors have no relevant financial or non-financial interests to disclose.

Funding. This work was supported by National Funds through FCT – Fundação para a Ciência e a Tecnologia, I.P., under the project UIDB/50008/2023 (Instituto de Telecomunicações), UIDB/05198/2023 (Centro de Investigação e Inovação em Educação, inED), UIDB/00194/2023 (CIDTFF), UID/06185/2023 (SPRINT - Sport Physical Activity And Health Research And Innovation Center) and under the doctoral scholarship 2022.09720.BD, and DOI identifier <https://doi.org/10.54499/2022.09720.BD>.

Ethical Approval. This study was approved by the Research Ethics Committee of Polytechnic University of Coimbra under the reference 101 CEIPC/2022, JUNE 22. All subjects provided their

informed consent, confirmed that they had read and understood the information, and were allowed to participate in the present study. They were debriefed upon completion.

Corresponding author. Correspondence concerning this article should be addressed to Rita Neves Rodrigues, Rua Dom João III, 3030-329, Coimbra, Portugal. Email: ritanevesrodrigues@hotmail.com

References

- Angeli, C. (2022). The effects of scaffolded programming scripts on pre-service teachers' computational thinking: Developing algorithmic thinking through programming robots. *International Journal of Child-Computer Interaction*, 31, 100329. <https://doi.org/10.1016/j.ijcci.2021.100329>
- Angeli, C., & Georgiou, K. (2023). Investigating the effects of gender and scaffolding in developing preschool children's computational thinking during problem-solving with Bee-Bots. *Frontiers in Education*, 7. <https://doi.org/10.3389/educ.2022.757627>
- Branco, N., & Ponte, J. (2014). Articulação entre pedagogia e conteúdo na formação inicial de professores dos primeiros anos: Uma experiência em Álgebra. In J. Ponte (Ed.), *Práticas profissionais dos professores de matemática* (pp. 379–408). Instituto de Educação, Universidade de Lisboa.
- Caldatto, M., & Ribeiro, C. (2020). Especificidades do conhecimento do professor de matemática na e para a formação: uma discussão em torno do programa de complementação pedagógica. *Revista Brasileira de Educação*, 25. <https://doi.org/10.1590/s1413-24782020250031>
- Canavarro, A., Brunheira, L., Vicente, M., & Brito, S. (2022). *Coletânea de tarefas - 3.º ano de escolaridade*.
- Canavarro, A., Oliveira, H., & Menezes, L. (2012). Práticas de ensino exploratório da matemática: o caso de Célia. *Investigação Em Educação Matemática*, 255–266.
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge.
- Conceição, T., Baptista, M., & Ponte, J. (2022). Examining Pre-service Science Teachers' Pedagogical Content Knowledge Through Lesson Study. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(1), em2060. <https://doi.org/10.29333/ejmste/11442>
- Dong, W., Li, Y., Sun, L., & Liu, Y. (2024). Developing pre-service teachers' computational thinking: a systematic literature review. *International Journal of Technology and Design Education*, 34(1), 191–227. <https://doi.org/10.1007/s10798-023-09811-3>
- Duarte, N., Ponte, J., & Faria, F. (2025). Introducing Exploratory Teaching in Preservice Teacher Education Through Lesson Study. *Education Sciences*, 15(3), 315. <https://doi.org/10.3390/educsci15030315>
- Duarte, N., Ponte, J., & Pinto, H. (2024). Estudo de aula como promotor do desenvolvimento do conhecimento de futuros professores sobre preparação de aulas. *Avances de Investigación En Educación Matemática*, 26, 21–39. <https://doi.org/10.35763/aiem26.5428>
- Ferguson, C. (2009). An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice*, 40(5), 532–538. <https://doi.org/10.1037/a0015808>
- Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). SAGE Publications Ltd.
- Freitas, Y., Abbasi, M., Brito-Costa, S., Pinto, R., Rato, V., & Martins, F. (2024). Exploratory teaching: Integrating applet to teach arithmetic multiplication operation. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(12), em2546.

<https://doi.org/10.29333/ejmste/15666>

- Gomes, A., Ferreira, D., & Gonçalves, C. V. (2023). Explorando tarefas matemáticas para a formação de professores do ensino básico: desafios e possibilidades. *Boletim Online de Educação Matemática*, 11, e0002. <https://doi.org/10.5965/2357724X112023e0002>
- Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, 42(1), 38–43. <https://doi.org/10.3102/0013189X12463051>
- Haşlamam, T., Mumcu, F., & Uslu, N. (2024). Fostering computational thinking through digital storytelling: a distinctive approach to promoting computational thinking skills of pre-service teachers. *Education and Information Technologies*, 1–27. <https://doi.org/10.1007/s10639-024-12583-5>
- Hsu, C.-Y., & Tsai, M.-J. (2024). Predicting Robotics Pedagogical Content Knowledge: The Role of Computational and Design Thinking Dispositions via Teaching Beliefs. *Journal of Educational Computing Research*, 62(5), 1159–1181. <https://doi.org/10.1177/07356331241236882>
- Humble, N., & Mozelius, P. (2023). Making programming part of teachers' everyday life – Programming affordances and constraints for K-12 mathematics and technology. *International Journal of Information and Learning Technology*, 40(1), 98–112. <https://doi.org/10.1108/IJILT-03-2022-0069>
- Karalar, H., & Aslan Altan, B. (2018). New technologies in microteaching: Is it possible for web 2.0 tools to affect prospective teachers' web pedagogical content knowledge and teacher self-efficacy? *International Online Journal of Education and Teaching (IOJET)*, 5(3), 535–551.
- Looi, C., Chan, S., Wu, L., Huang, W., Kim, M., & Sun, D. (2024). Exploring Computational Thinking in the Context of Mathematics Learning in Secondary Schools: Dispositions, Engagement and Learning Performance. *International Journal of Science and Mathematics Education*, 22(5), 993–1011. <https://doi.org/10.1007/s10763-023-10419-1>
- Marôco, J. (2021). *Análise Estatística com o SPSS Statistics (8ª Edição)*. ReportNumber.
- Martínez, M., Lévêque, O., Benítez, I., Hardebolle, C., & Zufferey, J. (2022). Assessing Computational Thinking: Development and Validation of the Algorithmic Thinking Test for Adults. *Journal of Educational Computing Research*, 60(6), 1436–1463. <https://doi.org/10.1177/073563312111057819>
- Ministério da Educação. (2021). *Aprendizagens essenciais de Matemática*. Lisboa: ME.
- Ortuño-Meseguer, G., & Serrano, J. (2024). Implementation and training of primary education teachers in computational thinking: a systematic review. *RIED-Revista Iberoamericana de Educacion a Distancia*, 27(1), 255–287. <https://doi.org/10.5944/ried.27.1.37572>
- Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (Vol. 181, Issue 4). <https://doi.org/10.4324/9781003117452>
- Palop, B., Díaz, I., Rodríguez-Muñiz, L., & Santaengracia, J. (2025). Redefining computational thinking: A holistic framework and its implications for K-12 education. *Education and Information Technologies*, 30, 13385–13410. <https://doi.org/10.1007/s10639-024-13297-4>
- Peracaula-Bosch, M., & Gonzalez-Martinez, J. (2022). Developing computational thinking among pre-service teachers. *QWERTY*, 17(1), 28–44. <https://doi.org/10.30557/QW000049>
- Pestana, M., & Gageiro, J. (2014). *Análise de dados para ciências sociais: A complementaridade do SPSS [Data analysis for social sciences: The complementarity of SPSS]*. Edições Sílabo, Lda.
- Ponte, J. (2012). *Estudiando El Conocimiento Y El Desarrollo Profesional Del Profesorado De*

- Matemáticas. In N. Planas (Ed.), *Teoría, crítica y práctica de la educación matemática* (pp. 83–98). Graó.
- Quaresma, M., Neves, R., & Macedo, A. (2022). Prática profissional e o estágio curricular supervisionado: experiências com lesson study na formação inicial de professores de matemática. *Educação Matemática Em Revista - RS*, 1(23). <https://doi.org/10.37001/EMR-RS.v.2.n.23.2022.p.135-148>
- Rodrigues, R. N., Costa, C., Brito-Costa, S., Abbasi, M., & Martins, F. (2025). Impact of a Training Program on Developing Computational Thinking in Pre-Service Primary School Teachers: From Theory to Practice. *Educational Process: International Journal*, 14, e2025037. <https://doi.org/10.22521/edupij.2025.14.37>
- Rodrigues, R. N., Costa, C., & Martins, F. (2024). Integration of computational thinking in initial teacher training for primary schools: a systematic review. In *Frontiers in Education* (Vol. 9, Issue 1330065, pp. 1–8). <https://doi.org/10.3389/feduc.2024.1330065>
- Santana, E., Ponte, J., & Serrazina, M. (2020). Conhecimento Didático do Professor de Matemática à Luz de um Processo Formativo. *Bolema: Boletim de Educação Matemática*, 34(66), 89–109. <https://doi.org/10.1590/1980-4415v34n66a05>
- Santos, J., Silva, J., & Lavicza, Z. (2025). Preparing Math Teachers for the Future: Analysing the Use of Technology in a Master’s Program. *The Electronic Proceedings of the 29th Asian Technology Conference in Mathematics*.
- Silva, R., Costa, C., Freitas, Y., Martins, F., & Cebrián-de-la-Serna, M. (2024). Educational robotics and primary school mathematics teaching: An analysis of pre-service teachers didactic-mathematical knowledge. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(10), em2515. <https://doi.org/10.29333/ejmste/15199>
- Silva, R., Costa, C., & Martins, F. (2024). Pre-service teachers’ perceptions towards integrating educational robotics in the primary school. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(4), em2419. <https://doi.org/10.29333/ejmste/14356>
- Sukkamart, A., Sermsri, N., Kantathanawat, T., Nakwijit, R., & Meekhobtong, S. (2024). Computer Education Student Teacher Complex Problem-Solving Skills Development using Computational Thinking and Visualization Tools. *Pakistan Journal of Life and Social Sciences (PJLSS)*, 22(2). <https://doi.org/10.57239/PJLSS-2024-22.2.00364>
- Sun, L., You, X., & Zhou, D. (2023). Evaluation and development of STEAM teachers’ computational thinking skills: Analysis of multiple influential factors. *Education and Information Technologies*, 28(11), 14493–14527. <https://doi.org/10.1007/s10639-023-11777-7>
- Tabachnick, B., & Fidell, L. (2021). *Using multivariate statistics* (7 th). Pearson.
- Tankiz, E., & Atman Uslu, N. (2023). Preparing Pre-Service Teachers for Computational Thinking Skills and its Teaching: A Convergent Mixed-Method Study. *Technology, Knowledge and Learning*, 28(4), 1515–1537. <https://doi.org/10.1007/s10758-022-09593-y>
- Täschner, J., Dicke, T., Reinhold, S., & Holzberger, D. (2025). “Yes, I Can!” A Systematic Review and Meta-Analysis of Intervention Studies Promoting Teacher Self-Efficacy. *Review of Educational Research*, 95(1), 3–52. <https://doi.org/10.3102/00346543231221499>
- Voon, X., Wong, S., Wong, L., Khambari, M., & Syed-Abdullah, S. (2022). Developing Computational Thinking Competencies through Constructivist Argumentation Learning: A Problem-Solving Perspective. *International Journal of Information and Education Technology*, 12(6), 529–539. <https://doi.org/10.18178/IJiet.2022.12.6.1650>

- Ye, H., Liang, B., Ng, O.-L., & Chai, C. (2023). Integration of computational thinking in K-12 mathematics education: a systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(1), 3. <https://doi.org/10.1186/s40594-023-00396-w>
- Yun, M., & Crippen, K. (2025). Computational Thinking Integration into Pre-Service Science Teacher Education: A Systematic Review. *Journal of Science Teacher Education*, *36*(2), 225–254. <https://doi.org/10.1080/1046560X.2024.2390758>
- Zaragoza, A., Seidel, T., & Hiebert, J. (2024). Exploring preservice teachers' abilities to connect professional knowledge with lesson planning and observation. *European Journal of Teacher Education*, *47*(1), 120–139. <https://doi.org/10.1080/02619768.2021.1996558>
- Zeng, Y., Yang, W., & Bautista, A. (2023). Computational thinking in early childhood education: Reviewing the literature and redeveloping the three-dimensional framework. *Educational Research Review*, *39*, 100520. <https://doi.org/10.1016/j.edurev.2023.100520>
- Zha, S., Jin, Y., Moore, P., & Gaston, J. (2020). Hopscotch into Coding: Introducing Pre-Service Teachers Computational Thinking. *TechTrends*, *64*(1), 17–28. <https://doi.org/10.1007/s11528-019-00423-0>

About the Contributor(s)

Rita Neves Rodrigues is a PhD student in Science and Technology Education Research of the University of Trás-os-Montes and Alto Douro, Portugal and an invited lecturer at the Polytechnic University of Coimbra. PhD Research Fellow at the Foundation for Science and Technology, researcher at the research Centre Didactics and Technology in Education of Trainers at the University of Aveiro (UIDB/00194/2023). Research interests include Mathematical Education, focusing on developing the didactic knowledge of pre-service teachers so that they can integrate the dimensions of Computational Thinking into their practices, simultaneously promoting learning of mathematical knowledge.

Email: ritanevesrodrigues@hotmail.com

ORCID: <https://orcid.org/0000-0001-8072-8453>

Cecília Costa is an Associate Professor at the School of Science and Technology of the University of Trás-os-Montes e Alto Douro, Portugal. With a PhD in Mathematics and Habilitation in Didactics of Science and Technology, she is the director of the doctoral course in Science and Technology Didactics, and she teaches Didactics of Mathematics in several teacher training courses and a researcher at the research Centre Didactics and Technology in Education of Trainers at the University of Aveiro (UIDB/00194/2023). Her main research areas are Sciences and Technological Education (STEM) Research, in particular: teaching practices and teacher mediation of student learning, teacher education and professional development, artefacts as epistemic tools to enhance STEM learning, and Instrumental Orchestration.

Email: mcosta@utad.pt

ORCID: <https://orcid.org/0000-0002-9962-562X>

Sofia Gonçalves has a professional trajectory in the field of education, combining teaching experience, pedagogical leadership, and scientific research. She holds a PhD in Educational Sciences, specializing in Teaching Organization, Learning, and Teacher Training. She is a researcher in European research projects, a Professor at the Polytechnic Institute of Coimbra – School of Education, Director of the Specialization Course in School Administration and Organization, and researcher at inED - Centre for Research and Innovation in Education (UIDB/05198/2023). She is the author of training programs on innovative educational practices.

Email: sofiagoncalves@esec.pt

ORCID: <https://orcid.org/0000-0002-9893-7875>

Fernando Martins is a Full Professor at the Polytechnic University of Coimbra - Coimbra Education School, Portugal. With Aggregate Degree in Child Studies and a PhD in Mathematics, he teaches Mathematics and Didactics of Mathematics subjects in Basic Education degrees and Master's in Training for Educators and Teachers. Researcher at the inED - Centre for Research and Innovation in Education (UIDB/05198/2023), Instituto de Telecomunicações (UIDB/50008/2023), SPRINT – Sport Physical Activity and Health Research & Innovation Center (UID/06185/2023) and Research Group in Training, Education, and Intervention. Research interests include mathematical knowledge for teaching, mathematical methods applied to sports sciences problems and engineering, social network analysis, elementary mathematics, computational thinking, educational robotics, and STEAM education.

Email: fmlmartins@esec.pt

ORCID: <https://orcid.org/0000-0002-1812-2300>

Publisher's Note: *The opinions, statements, and data presented in all publications are solely those of the individual author(s) and contributors and do not reflect the views of Universitepark, EDUPIJ, and/or the editor(s). Universitepark, the Journal, and/or the editor(s) accept no responsibility for any harm or damage to persons or property arising from the use of ideas, methods, instructions, or products mentioned in the content.*
