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STEAMING AHEAD

FOSTERING CRITICAL THINKING, PROBLEM-SOLVING AND CREATIVITY

STEAM
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EDITED BY
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Title

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Contents

X. The Exploration of the SuperDoc Robot through an Explanatory Teaching Model

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Introduction

The present work aims primarily to develop: mathematical learnings within the subtopic of Spatial Orientation in the Geometry and Measurement theme; the theme of Data and Probabilities, and the dimensions of Computational Thinking. To this end, a set of tasks was energized that encompasses not only the curricular area of Mathematics but also Portuguese and Environmental Studies. This set of tasks was designed for the 2nd-grade class that the trainee teachers followed within the context of Supervised Practice in Primary Education. In order to respond to the students' interests, they decided to also introduce Educational Robotics (RE), as it is a pedagogical tool that promotes significant learning (Pedro et al., 2017). The tasks are divided into three sessions, each of which was organized according to the four phases of the Exploratory Teaching model (Stein et al., 2008, cited by Canavarro et al., 2013). As it would be the first time the class would engage with this teaching model, and considering that the head teacher does not set a specific time for task completion, they decided it would be important to maintain this dynamic. Additionally, they considered it pertinent that the tasks should be divided into three sessions according to the learning objectives they aimed to develop.

To present a logical and coherent structure, this work is divided into five parts. Firstly, the literature review will be presented, highlighting the importance and contextualizing the evolution of Computational Thinking. The second part will concern the rationale and context, in which the practice implemented by the trainee teachers is contextualized, and they reflect on its importance in promoting mathematical learning. Next, the third part will refer to the description of the educational practice and its implementation, i.e., the practice is framed, and the respective planning is presented. In turn, the fourth part, the evaluation of the implementation of the practice and main results, will consist of a reflection on the results obtained and where some conclusions are drawn. Finally, in the fifth and last part, the main contributions of the educational practice proposal will be presented clearly.

Literature Review

The concept of Computational Thinking (CT) has been around for several decades. It was in 1980 that Papert first argued that children should develop logical reasoning processes, and for this, he created a programming language called LOGO (Grover & Pea, 2013). This programming language allowed the development of problem-solving skills.

In 2006, Jeannette Wing, a researcher at the National Science Foundation (NSF), published the article "Computational Thinking." In it, she stated that CT corresponds to a set of cognitive tools associated with computer science (Wing, 2006). Years later, in 2014, Wing reformulated her conception of CT, defining it as a process involving the formulation of problems and expressing their solutions, comparing humans with computers. In this sense, it was Wing who encouraged and drove the integration of this mathematical ability into the school curriculum (Grover & Pea, 2013).

Over time, Computational Thinking has undergone reforms, making it a concept that is not consensual among the scientific community (Ausiku & Matthee, 2021, as cited in Rodrigues et al., 2022). However, most definitions state that it is a "set of essential skills for problem-solving" (Ausiku & Matthee, 2021, cited by Rodrigues et al., 2022), which include critical thinking and algorithmic thinking of students (Özcan et al., 2021; Voon et al., 2022, cited by Rodrigues et al., 2022).

According to Canavarro et al. (2021), CT fosters the development, in an integrated manner, of practices such as "abstraction, decomposition, pattern recognition, analysis and definition of algorithms, and development of debugging and optimization habits." The "abstraction" dimension corresponds to the ability to select the essential characteristics or information from a given problematic situation (Angeli et al., 2019). The Computational Thinking dimension of "decomposition" allows the student to break down a complex problem into less complex tasks (Albuquerque, 2021). Meanwhile, the "pattern recognition" dimension, when developed, makes students capable of recognizing and identifying common features in the problem-solving process (Canavarro et al., 2021). The "debugging" dimension allows for the correction of errors, testing them, and thereby optimizing a solution (Canavarro et al., 2021). Finally, the "algorithmic" dimension promotes students' ability to develop a step-by-step procedure to address a problematic situation (Canavarro et al., 2021).

In 2021, Computational Thinking emerged for the first time in Portugal as a mathematical capability in the Essential Learning guidelines. This guiding document clarified that Computational Thinking does not have to relate exclusively to Mathematics, but can and should develop in various curricular areas (Moschella & Basso, 2020, cited by Rodrigues, 2022).

Computational Thinking is, according to Wing (2021), "a fundamental ability for everyone, not just for computer engineers" (p.2). It is an ability that includes a set of cognitive tools and allows building knowledge through research.

Integrated practices intentionally combine different curricular areas and are, according to Paixão (2015, cited by Rodrigues et al., 2015), indispensable in the 21st century as they develop in students' essential skills and competencies for their daily life. In an increasingly complex and unpredictable world, it is crucial for schools to be prepared to educate citizens for constant change. In this sense, and since some researchers cited by Sá & Paixão (2013) mention in their studies that schools have not evolved equitably in terms of scientific-technological knowledge and the development of educational policies, it is essential to rethink these policies and the quality of teacher training. According to Ponte (2012), didactic knowledge is divided into four interdependent dimensions. A teacher must have knowledge of Mathematics for learning, to be able to interpret and adapt the way of working with mathematics in the classroom, not limiting themselves to scientific knowledge (Ponte, 2012). On the other hand, the teacher must know the curriculum and know how to manage it according to their context (Ponte, 2012). The teacher must also have knowledge of students and their learning processes to try to respond to their interests, providing more meaningful learning (Ponte, 2012). Finally, the teacher must be able to design tasks, adopt strategies, organize student work, and evaluate to promote meaningful learning, demonstrating knowledge of their Teaching Practice (Ponte, 2012). These dimensions of didactic knowledge are presented in figure 1 below.

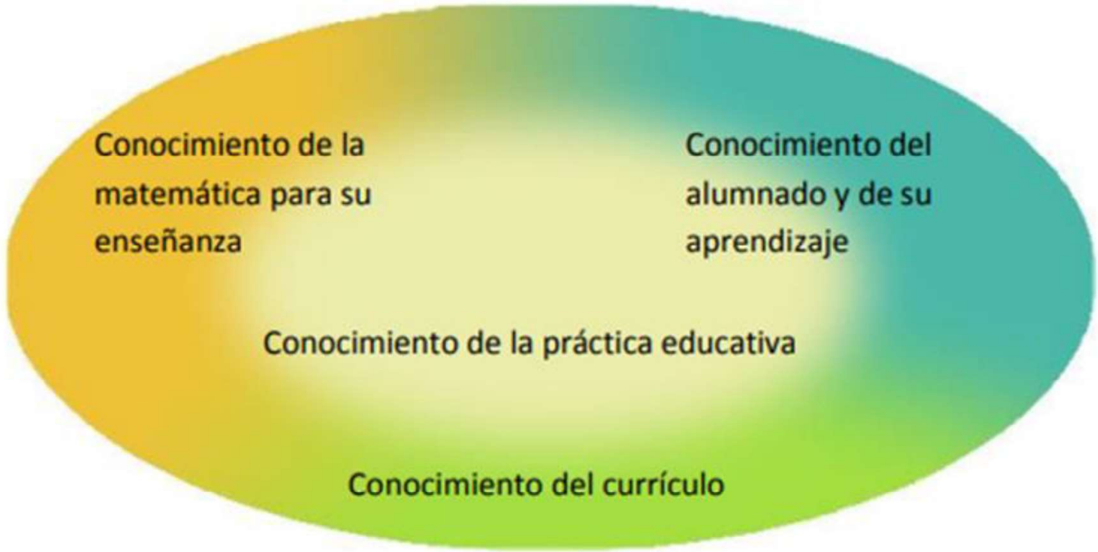


Figure 5. Dimensions of Didactic Knowledge (Ponte, 2012)

<u>Key</u>

- 'Conocimiento de la matemática para su enseñanza' – Knowledge of Mathematics for Teaching
- 'Conocimiento del alumnado y de su aprendizaje' – Knowledge of Students and Their Learning
- 'Conocimiento de la práctica educative'' – Knowledge of Educational Practice
- 'Conocimiento del curriculo' – Knowledge of the Curriculum

Foundations and Context

The Exploratory Teaching Model

The Exploratory Teaching Model was introduced to develop the dimensions of Computational Thinking. In this sense, and based on the interests of the class, proposals were made that involved Educational Robotics at the same time.

Exploratory Teaching is a teaching model organized in four phases (Stein et al., 2008, cited by Canavarro et al., 2013): task introduction, task realization, task discussion, and systematization of learning. In the first phase, the introduction, the goal is for the students to take ownership of the task. For this, the teacher must clarify and familiarize the students with the context of the tasks. In the task realization phase, all students must know how to work in groups to develop reasoning and advance in the tasks. The teacher, to ensure that students develop the tasks with mathematical quality, should circulate around the room and ask guiding questions that help them develop their reasoning. In the third phase, the task discussion, the aim is for one group of students to present their solutions and the others to feel confident to comment, comparing different reasoning. In this phase, the teacher should mediate student interactions and encourage them to compare solutions, developing critical thinking. In the last phase of the class, the systematization of learning, the teacher should systematize the learning acquired throughout the exploration and resolution of tasks through questioning (Canavarro et al., 2013).

This teaching model is distinguished by the roles played by the teacher and the students (Ponte, 2005, cited by Canavarro et al., 2013), throughout the four phases of the class, as previously mentioned. Each teacher is responsible for adapting and defining the learning objectives, taking into account the specificities of their class. For this, the teacher must select the tasks and respective strategies to be developed during the class.

The practice implemented over the three sessions, which will be presented later, is appropriate as we start from Exploratory Teaching to develop the dimensions of Computational Thinking (abstraction, decomposition, algorithmics, debugging, and pattern recognition). The five dimensions were developed through interdisciplinarity and the following tasks:

- "Indicate all the elements you think are important to make a cake." – Abstraction;
- "What is the path you take to collect the ingredients for your cake? Don't forget the cake has to go in the oven." – Algorithmics;
- "What other cake can you make? With what ingredients?" – Decomposition;
- "Do you think you could make other cakes with the ingredients on the mat? If so, which ones?" – Debugging;
- "What ingredients do these cakes have in common?" – Pattern Recognition.

During the weeks of observation, in the context of Supervised Practice in 1st grade CEB, it was noted that students had some difficulties in defining their laterality. In this regard, and in conversation with the cooperating teacher, it was decided to implement tasks within the scope of Educational Robotics, also developing Spatial Orientation.

Educational Robotics

Educational Robotics is a pedagogical tool that promotes significant learning, as the student plays an active role in their own learning (Pedro, A. et al., 2017). One of its contributions to the teaching-learning process is to make the student question, think, and seek solutions, developing problem-solving skills (Ribeiro et al., 2011). The use of Educational Robotics allows students to learn in a playful way, creating a motivating learning environment (Pedro, A. et al., 2017).

According to Benitti (2012), learning is not guaranteed simply by using Educational Robotics in the classroom. There are influencing factors such as the appropriate choice of the robot, the methodology used, the knowledge the teacher has about robotics, and the space available in the classroom for experimentation and movement of the robot (Oliveira, 2013).

Data and Probabilities

The topic Data and Probabilities, initially called Data Organization and Treatment (OTD) as stated in the Basic Education Mathematics Program (2007), emerged with the purpose of enabling students to "read and interpret data organized in the form of tables and graphs, as well as to collect, organize, and represent them to solve problems in various contexts related to their daily lives" (p. 26).

The New Essential Learnings (ME, 2021), in addition to including Computational Thinking as a transversal mathematical ability, renamed OTD to Data and Probabilities, making it a mathematical theme. The aim of Data and Probabilities is to develop in children the ability "to better understand their surroundings, make decisions, ask new questions, and approach uncertainty" (p. 10).

The 2nd grade class with which this work was conducted has been addressing this mathematical theme. In the week prior to this implementation, a table of absolute frequency about favourite fruit had been constructed collectively. From the data in this table, the students created pictograms and point graphs. Therefore, the ability to recognize and analyse an absolute frequency table was identified as prior knowledge. In this sense, session 3 focused on a task intended to develop one of the dimensions of Computational Thinking, so that, through the identified cakes, the students could create an absolute frequency table organizing the collected data.

Formative Assessment Technique

To understand whether the learning objectives were achieved throughout the tasks, the Formative Assessment Technique - Traffic Light Cards was used. Formative assessment is a type of evaluation aimed at "actively contributing to students learning more and better, with understanding and more depth" (Fernandes, 2021, p.4). Being an assessment for and as learning, it encourages active and intentional student participation in the teaching-learning process and the co-construction (teacher-student) of ways to monitor progress (Lopes & Silva, 2020, p.5). This type of assessment fosters responsibility and awareness in students, as they must be able to reflect on and evaluate their work (Lopes & Silva, 2020, p.19).

Description of Educational Practice and Its Implementation

Curricular Framework; Students' Prior Knowledge; Resources Used; Expected Duration; Evaluation

The Supervised Educational Practice of the 1st Cycle of Basic Education takes place at the Basic School of Assafarge with the cooperation of teacher Elisabete Pires. The class where the practice took place is 2nd Grade, consisting of 18 students, 10 being female and 8 being male. Overall, the class is quite interested, curious, and developed in terms of Reasoning and Problem-Solving skills. The students are capable of mobilizing reasoning, presenting logical and diversified problem-solving processes, making discussions more enriching and mathematically quality (ME, 2017, p. 23).

The primary goal of this practice is to promote the development of the dimensions of Computational Thinking through the theme Data and Probabilities, considering the Exploratory Teaching model. In this sense, an interdisciplinary proposal was developed, taking into account mathematical abilities and themes. The proposal emerged following the World Food Day and from a suggestion of the teacher based on the interests of the students. Thus, the trainee teachers proposed introducing a new type of text, the recipe, using Educational Robotics. Through the cake recipe, students were alerted to the necessary ingredients for baking a cake and how they can be substituted with healthier ones. A practical example used was replacing white sugar with brown sugar.

For the proposed tasks, students were expected to be able to: recognize quantities; understand spatial orientation concepts (right, left, front, and back); analyse and interpret an absolute frequency table. The resources needed for the three sessions were: exploration sheet - Resolution (Appendix 1); exploration sheet - Systematization (Appendix 1); writing materials; PowerPoint for systematization (Appendices 2 and 3); four SuperDoc robots; four educational mats; chalk; daily math notebook; ingredients for baking the cake; kitchen utensils (mixer, spatula; mug; spoon); Traffic Light Cards (TAF). The three sessions were planned for two days, corresponding to the context of Supervised Educational Practice. To assess the acquired learning, according to the previously defined learning objectives, the Formative Assessment Technique - Traffic Light Cards was chosen.

Organizational Design of the Learning Environment

The implemented educational practice was carried out over two days, but it is divided into three sessions. On Monday, the first part of the exploration sheet, corresponding to session 1, was completed, totalling 165 minutes. It was also possible to start session 2, the second part of the exploration sheet, totalling 100 minutes. The next day, the second session was concluded, totalling 115 minutes, and the third session was fully completed, resulting in 85 minutes.

During the three sessions, the room was organized into four islands, so four groups of four or five members were formed. Each island consisted of two tables to facilitate group work and the handling of the robot. Only during the third session was a table added at a strategic point so that all groups could observe and assist in the cake-making process.

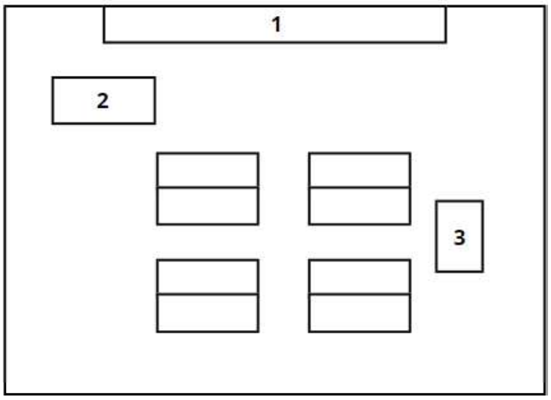


Figure 6. Representative Drawing of the Classroom Layout.

<u>Key</u>

1. Whiteboard
2. Desk of the Cooperating Teacher
3. Baking Table

Description of the Class Development

The set of tasks presented is divided into three sessions. Since the implemented proposal is interdisciplinary, each session initially presents a table containing learning objectives from the mentioned curricular areas.

Session 1

Grade Level	Curricular Area:	Duration
2nd Year	Mathematics	165 minutes

Previous Knowledge	Resources
Recognize quantities.	· Exploration Sheet – Resolution: Part 1 (Appendix 1) · Exploration Sheet – Systematization: Part 1 (Appendix 1) · Writing materials · Systematization PowerPoint (Appendix 2)

Curricular Area	Domain	Contents	Learning Objective	Competence Areas of the Student Profile
Portuguese	Orality	Comprehension	Select relevant information according to the objectives for the task.	A. Languages and Texts B. Information and Communication E. Interpersonal Relationship F. Personal Development and Autonomy I. Scientific and Technical Knowledge.
	Reading and Writing	Reading	Understand the meaning of texts with narrative and descriptive characteristics, associated with different purposes (recreational, aesthetic, informative). Identify explicit information in the text. Identify and refer to the essentials of read texts.	
		Writing	Write short texts for various purposes (narrate, inform, explain).	

Theme		Topic	Subtopic	Learning Objective	Competence Areas of the Student Profile
Mathematical Themes	Numbers	Numerical Relations	Basic Multiplication Facts	Understanding the Doubles of Numbers.	D. Critical Thinking E. Interpersonal Relationships F. Personal Development and Autonomy I. Scientific Knowledge.
Mathematical Skills		Computational Thinking	Abstraction	Extracting the Essential Information from a Problem.	

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="4">Introduction of the task (15 minutes)</td><td colspan="2">Lesson development</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members.
Distribution of exploration sheets (Part 1) to each group.
Presentation of tasks to be performed and brief explanation of the work methodology, the Exploratory Teaching model.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>Present the tasks to the class, ensuring understanding by all students:
Familiarize with the context of the task;
Clarify the interpretation of the task.</td><td>Organize the students, taking into account their level of development, forming heterogeneous groups.
Divide the classroom into four islands.
Distribute the exploration sheets.
Explain the working methodology to the whole group.</td></tr>
<tr><td rowspan="4">Task Execution (70 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Students solve the tasks from Part 1 of the exploration sheet in groups, knowing that all members must participate actively. In each group, it's important to have good communication, knowledge sharing, and reach a consensus to decide on the answer that best suits the question posed.
The trainee teachers circulate around the classroom to observe the different reasoning of the students and to clarify any doubts, in order to select the groups that will present their solutions.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>Ensure that the students solve the tasks.
Ask for justifications for the given answers.
Question the members of each group about the presented solutions.
For Task 1: “What did you extract from the text to affirm that it's a recipe?"
For Task 2: “Why did you order it this way?"
For Task 3: “Where can you find this information?"
For Task 4: “What information do you consider important for solving the problem?"
“How did you think?"
“What led you to think this way?"</td><td>Move around the groups and observe the resolutions.
Question the students, helping them solve the questions.
Provide moments of interaction among the group members.
Remind them that they are expected to work as a group, contributing to the resolution of the problematic situation.
Reinforce the importance of recording their reasoning on the exploration sheet.
Identify and select the various resolutions (different reasoning and difficulties) for later discussion and presentation of the answers.</td></tr>
<tr><td></td><td colspan="2">Development of the Lesson</td></tr>
</table>

Discussion of the task (20 minutes)	In the different questions, different groups are selected, with selection criteria based on errors, difficulties, and reasoning. In addition to the selected group, the others provide comments according to their reasoning. The discussion is mediated by the teachers.	
	Promotion of mathematical learning	***Classroom management***
	– Ask them to clarify and justify their solutions. – Encourage interactions between the presenting group and the other groups. – Question the students about the different reasoning used for the same question. – Encourage students to compare the various solutions presented by the groups.	– Create a conducive environment for presentation and discussion. – Define a presentation order. – Inform that the presenting group should explain their reasoning clearly. – Promote and manage student participation in the discussion.
Mathematical learning systematization (60 minutes)	***Development of the Lesson***	
	Presentation of the teachers' proposed solutions through a PowerPoint. Recording the solutions presented on new exploration sheets, distributed in advance.	
	Promotion of mathematical learning	***Classroom management***
	Systematize the acquired knowledge: Extract the necessary information from a problem (abstraction); Orally question the students about the answers to each task.	– Create a conducive environment for the systematization moment. – Distribute the new exploration sheets. – Project the solutions to the tasks. – Ensure the written recording of the proposed solutions.

Session 2

Grade Level	***Curricular Area:***	***Duration***
2nd Year	Mathematics	215 minutes

Prior Knowledge	***Resources***
Recognize concepts of spatial orientation (right, left, front, and back).	Exploration Sheet – Resolution: Part 2 (Appendix 1) Exploration Sheet – Systematization: Part 2 (Appendix 1) 4 SuperDoc robots + 4 Pedagogical Carpets (Attachment – Figure 2) Writing materials Systematization PowerPoint (Appendix 3)

Curricular Area	***Domain***	***Contents***	***Learning Objective***	***Competence Areas of the Student Profile***
Portuguese	Oral communication	Comprehension	Select relevant information based on the task's objectives.	G. Information and communication

				I. Scientific, technical, and technological knowledge
Study of the Environment	Nature		Reflect on behaviours and attitudes that contribute to individual and collective physical and psychological well-being, whether experienced or observed. Identify situations and behaviours that pose risks to individual and collective health and safety, proposing appropriate preventive and protective measures.	C. Languages and texts D. Information and communication F. Personal development and autonomy I. Scientific and technical knowledge

Theme		***Topic***	***Subtopic***	***Learning Objective***	***Competence Areas of the Student Profile***
Mathematical Topics	Geometry and Measurement	Spatial Orientation	Routes	Create and represent routes using the terms "turn right," "turn left," "up," "down," and "forward" to reach your destination.	
Mathematical Abilities		Computational Thinking	Abstraction Decomposition Pattern Recognition Algorithmic Thinking Debugging	Extract essential information from a problem. Structure problem-solving into stages of lower complexity to reduce the problem's difficulty. Recognize or identify patterns in the problem-solving process and apply effective ones to solve similar problems. Develop a step-by-step procedure (algorithm) to solve a problem so that it can be implemented in technological resources, even if it is not necessarily implemented. Seek and correct errors, test, refine, and optimize a given solution presented.	C - Reasoning and problem-solving D - Critical and creative thinking E - Interpersonal relationships F - Personal development and autonomy I - Scientific, technical, and technological knowledge J - Awareness and mastery of the body

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="4">Introduction of the task
(10 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members each;
Discussion about the precautions to take when handling the robots and educational mats;
Distribution of exploration sheets (Part 2) to each group.
Presentation of tasks related to Part 2 of the exploration sheet.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Clarify the interpretation of the task.
- Remind students of the precautions to take with the robots and educational mats:
"Do not scratch or dirty the educational mats."
"The materials do not belong to us and were borrowed, so we should return them as we received them."
"The robot is not a toy."
"Pay attention to the instructions you give to the robot to prevent it from falling and breaking."</td><td>- Organize students, taking into account their learning pace, forming heterogeneous groups, considering students with Specific Needs, integrating them into groups with students whose learning pace and reasoning ability are more developed.
- Divide the room into four islands.
- Distribute the exploration sheets.</td></tr>
<tr><td rowspan="4">Task Execution
(120 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Students solve the tasks of Part 2 of the exploration sheet in groups, knowing that all members must participate actively. It is important for each group to have good communication, share knowledge, and reach a consensus to decide on the answer that best fits the question posed.
The trainee teachers circulate around the room to observe the different reasoning processes of the students and clarify any doubts, selecting the groups that will present their solutions.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that students solve the tasks.
- Clarify doubts.
- Question the members of each group about the resolutions presented:
Task 1 "What are you doing?"; "How did you figure this out?"
Task 2 "What path are you going to take?"; "Have you thought about all the steps you need to take? And how will you represent them?"; "Did you follow all the instructions?"; "Did you manage to make the path you had in mind with the robot?"
Task 3 "What other cake did you think of making?"; "What ingredients do you need?"; "Why that cake and not another one?"; "Did you gather all the ingredients for your cake?"
Task 4 "Can you make other cakes?"; "With what ingredients can you make them?"
Task 5 "What does 'in common' mean?"; "What are the common ingredients?"</td><td>- Circulate among the groups and observe the resolutions.
- Question the students, helping them to solve the questions.
- Provide moments of interaction among the group members.
- Remind them to work in groups, contributing to the resolution of the problem situation.
- Emphasize the importance of recording their reasoning on the exploration sheet.
- Identify and select various resolutions (different reasoning and difficulties) for later discussion and presentation of answers.</td></tr>
<tr><td rowspan="2">Discussion of the task
(25 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">In different questions, different groups are selected, with selection criteria based on errors, difficulties, and reasoning. In addition to the selected group, the rest comment according to their reasoning.
The discussion is mediated by the teachers.</td></tr>
</table>

	Promotion of mathematical learning	***Classroom management***
	- Ask them to clarify and justify their resolutions. - Encourage interactions between the presenting group and the other groups. - Question the students about the different reasoning used for the same question: "Do all groups think this way?". "Does any group have a different resolution?". "Did they find more solutions?". - Encourage students to compare the various solutions presented by the groups.	- Create a conducive environment for presenting and discussing resolutions. - Define a presentation order. - Inform that the presenting group should explain their reasoning clearly. - Promote and manage student participation in the discussion.
Mathematical learning systematization (60 minutes)	***Development of the Lesson***	
	Presentation of the trainee teachers' proposed solutions through a PowerPoint. Recording of the solutions presented on the new exploration sheets, distributed in advance.	
	Promotion of mathematical learning	***Classroom management***
	Systematize the acquired learning: Clarify the robot's functions (arrows, trash, star, on/off); Relate spatial orientation to reality (our body) and the robot through concrete examples. Understand that there are different reasoning processes for solving the same problem.	- Create a conducive environment for the systematization moment. - Distribute the new exploration sheets. - Project the resolutions of the tasks. - Ensure the written recording of proposed solutions.

Session 3

Grade Level	***Curricular Area:***	***Duration***
2nd Year	Mathematics	85 minutes

Prior Knowledge	***Resources***
Analyze and interpret an absolute frequency table.	Chalk. Writing materials. Mathematics daily notebook. Ingredients for making the cake. Kitchen utensils (mixer, mug, spoon). Traffic Light Cards (TAF).

Curricular Area	***Domain***	***Contents***	***Learning Objective***	***Competence Areas of the Student Profile***
Portuguese	Reading and Writing	Reading	Understand the meaning of texts with narrative and descriptive characteristics, associated with different purposes (entertainment, aesthetics, informative). Identify and mention the essentials of read texts.	A. Languages and texts B. Information and communication

Theme	***Topic***	***Subtopic***	***Learning Objective***	***Competence Areas of the Student Profile***

Mathematical Topics	Data	Statistical Questions, Data Collection, and Organization	Data collection Table of absolute frequencies	Collect data through a given data collection method. Use a table of absolute frequencies to organize data related to the cake they would like to taste.	A. Languages and texts B. Information and communication C. Reasoning and problem solving I. Scientific knowledge

Assessment of the Lesson
Formative Assessment Technique - Traffic Light Cards, taking into account the following questions: - Did they work well in groups? - Did they understand all the robot's functionalities? - Were they able to program the robot according to the path they had in mind? - Did they enjoy the tasks? - Would they like to work this way again?

<table>
<tr><th>Phase of the lesson (Time)</th><th colspan="2">Description of the lesson development</th></tr>
<tr><td rowspan="4">Introduction of the task (5 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">Organization of students into four groups of four or five members, maintaining the same groups from the previous session.
Discussion about the different cakes that could have been made using the elements present on the educational mat.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Remind students of the elements present on the mat and the answers they provided regarding the recipes that could be made.
"Do you remember the recipes you suggested besides the orange cake?"
"What other cakes can we make?"</td><td>- Inform students that they should remain in the same groups as the previous session.
- Divide the classroom into four islands.</td></tr>
<tr><td rowspan="4">Task Execution (20 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The teachers record on the board the different cakes that can be made, as students identify them.
The identified cakes will be used to create a frequency table with the title "The cake I would like to taste...".
Students take turns going to the board to select the cake they would like to taste.
Later, students will count the total number of votes for each cake.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that all students participate in the construction of the frequency table.
- Question students about the organization of data in a frequency table.</td><td>- Question students about their preferences.
- Manage student participation.
- Record on the board the different cakes mentioned by the students.</td></tr>
<tr><td rowspan="4">Discussion of the task (10 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The students observe and analyse the table to deduce the votes for each cake, subsequently identifying the most voted cake. This cake will be prepared by all.</td></tr>
<tr><td>Promotion of mathematical learning</td><td>Classroom management</td></tr>
<tr><td>- Ensure that students correctly analyse the data present in the table.
- Question students about which cake they think we will bake.</td><td>- Create a conducive environment for discussion.
- Manage student participation.</td></tr>
<tr><td rowspan="2">Mathematical learning systematization (50 minutes)</td><td colspan="2">Development of the Lesson</td></tr>
<tr><td colspan="2">The students record the frequency table "The cake I'd like to taste..." in their daily maths notebook.
The student teachers, guided by the students' indications, prepare the cake.
Implementation of the Formative Assessment Technique - Semaphore Cards.</td></tr>
</table>

	Promotion of mathematical learning	*Classroom management*
	– Encourage student participation. – Ask students orally: "What is the first step in the preparation method?" "After separating the egg whites from the yolks, what comes next?" "How many cups of sugar?" "How do we know when the egg whites are well beaten?" "And now, where are we going to make the cake?"	– Create a conducive atmosphere for the systematization moment. – Ensure the written record of the frequency table. – Manage student interventions.

Student Learning Regulation

To promote mathematical learning in students, various strategies were adopted throughout the four phases of the Exploratory Teaching model. These encompassed clarifications and guiding questions to ensure that students understood, interpreted, solved, and presented their reasoning with mathematical quality.

During the sessions, the introduction phase was characterized by ensuring that students understood the context of the tasks. In the task performance phase, it was intended that all students participated in the development of the task. This development was ensured by the student teachers circulating among the different groups and asking guiding questions such as: "Where can you find that information?"; "How did you think?"; "Did you follow all the instructions?"; "Why that cake and not another one?"; "Can you make other cakes?"; and "What does 'in common' mean?". These maintained the cognitive challenge and the students' autonomy. The task discussion phase involves promoting the mathematical quality of the students' presentations. For this, the groups that were not presenting their solutions commented and compared the different reasonings to clarify the ideas presented or to clarify doubts. Regarding the last phase of the class, the systematization of learning, it aims to systematize the learning acquired throughout the exploration and resolution of tasks. Thus, in a large group, students were orally questioned about the solutions, and as they responded, our solution was presented. This presentation was made through a PowerPoint prepared by the student teachers. Thus, the student teachers could perceive the students' understanding of what was done, having clarified doubts with real situations.

The implementation of this educational practice concluded with the Formative Assessment Technique – Traffic Light Cards. For this TAF, the following questions were considered: "Did you know how to work in a group?"; "Did you understand all the functionalities of the robot?"; "Were you able to program the robot according to the path you thought of?"; "Did you like the activity?"; and "Would you like to work this way again?". The questions were asked in a large group, and each student responded with a red card (no), a yellow card (somewhat), or a green card (yes).

Regarding the evaluation by the student teachers, we based it on the Assessment Grids present in Lopes & Silva (2020). The assessment grid (Appendix 4) aimed to evaluate the students' competencies, with criteria such as participation, cooperation, relationship, reasoning, expressing ideas, arguing, and individual commitment. The assessment scale includes the levels Insufficient, Sufficient, Good, and Very Good (Appendix 5).

Evaluation of the Implementation of the Practice and Main Results

Assessment and Reflection

In planning this educational practice, the student teachers encountered some difficulties. These difficulties were: introducing a new teaching model, both for the student teachers and our students; planning interdisciplinary practices; formulating the questions to be present in the exploration sheet and the strategies to be adopted, with the implementation aiming to develop the dimensions of Computational Thinking.

During the implementation of the educational practice, the student teachers were confronted with challenges, among which stand out: group work, formulating guiding questions, and the students' frustration. Since the class usually did not work in small groups, the student teachers understood the importance of developing "self-confidence, motivation to learn, self-regulation, initiative and making informed decisions" and that they could "recognize, express and manage emotions, build relationships, establish goals." (ME, 2017, pp.25-26). In this sense, the student teachers chose to carry out group tasks providing students with moments of sharing conceptions and reasoning (Oliveira et al., 2013). Thus, one of the difficulties that the student teachers had to overcome was formulating simple guiding questions, maintaining the cognitive challenge, forcing the students to be autonomous and to try to find an appropriate answer (Stein et al., 2008, cited by Oliveira et al., 2013). The fact that the student teachers maintained the cognitive challenge in the work developed by the students in small groups, considering that they were familiar with questions that lead to direct answers, led them to frustration. This frustration was one of the biggest challenges for the student teachers. Thus, the role of the student teachers was crucial to help students understand the benefits of collaborative learning. It is also added that another determinant aspect was the choice of the exploratory teaching model to implement the educational practice.

From the implementation of this practice, the student teachers highlighted that they had to make some adjustments, such as in the systematization of learning phase where they had to change the initially planned strategy. The objective of this phase was to ensure that the students had achieved the defined goals and, for this purpose, the student teachers used oral questioning. Thus, to systematize the learning, it was intended that students would subsequently copy the presented solutions onto the systematization sheets. However, in the first session, the student teachers realized that the students were not participating as expected. For this reason, in the second session, the student teachers asked the students to only copy the solution for some tasks, while the rest were answered orally.

Introducing the Exploratory Teaching model in the 2nd-grade class was indeed a valuable addition, as the students were able to present various reasoning and explain them clearly to the rest of the class. This teaching model allowed not only the development of the dimensions of Computational Thinking but also the competencies of the Students' Profile at the End of Compulsory Schooling. Among the various competencies, emphasis is given to the following: Critical and Creative Thinking; Reasoning and Problem-Solving; Scientific, Technical, and Technological Knowledge; Interpersonal Relationships; Personal Development and Autonomy (ME, 2017).

Presentation of Main Results

The Exploratory Teaching model allowed students to build their own knowledge through sharing ideas within the group (Oliveira et al., 2013). This sharing was promoted by managing and guiding the group so that all members participated, presenting their reasoning clearly. We highlight below the tasks that generated the most doubts and a greater diversity of reasoning.

In the task "Indicate all the elements you think are important to make a cake.", the groups initially showed some difficulty in interpreting what "elements" meant. Through the following dialogue excerpt, we can understand that the students in this group tried to extract the essential information from the problem. In this case, as it was a recipe, they managed to identify the important elements, the ingredients.

Group	***Reasoning***
Group 4	A Student: All of them. A Student: Wait! Eggs first, because I always see my mom adding them. A Student: Yes, there must always be eggs. A Student: Eggs, orange... yes, because it's an orange cake.

During the execution of this task, the students developed some of the intended competencies (Martins et al., 2017), such as critical and creative thinking as well as interpersonal relationships, as they debated various ideas to reach the final answer. We highlighted this excerpt because we found it interesting that they mentioned the ingredients in the order as their mothers usually do.

The task "This recipe is for 4 people. If you want to make it for 8 people, what do you have to do?" was the one that caused the most disagreement and therefore provided moments of debate among the members of each group. This task tested the students' ability to share, have a critical spirit, listen, respect, and accept different proposals (ME, 2017), as well as reach a consensus on the answer they would present. We highlight some of the solutions presented to us and the reasoning that led the groups to these conclusions.

Group	**Reasoning**
Group 1	Intern Teacher: So, if you have to make a cake for 8 people... A Student: We have to draw the ingredients! Intern Teacher: What are you doing? A Student: Drawing the eggs.

<table>
<tr><td></td><td>Intern Teacher: But how are you planning it?

A Student: The cake will need 6 eggs, but if it's for 8 people, it will need 12 eggs.

Intern Teacher: Why?

A Student: Because 6 plus 6 is 12.

A Student: And how many cups of sugar will it be?

A Student: It has to be two. It has to be the same number more than before.

Intern Teacher: Why? Did we increase or decrease the number of people?

A Student: Since we increased the number of people, we have to increase the ingredients.

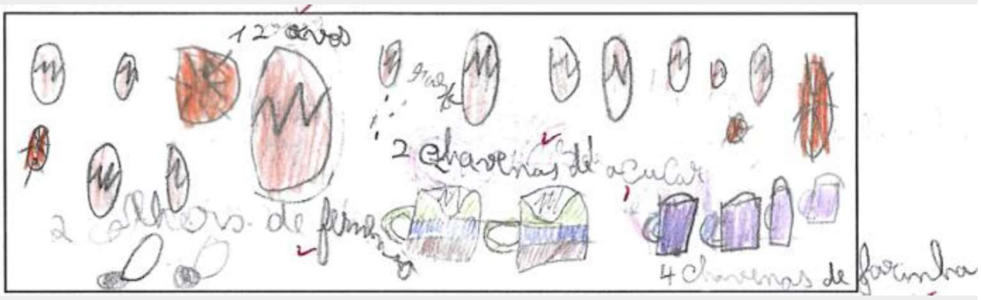
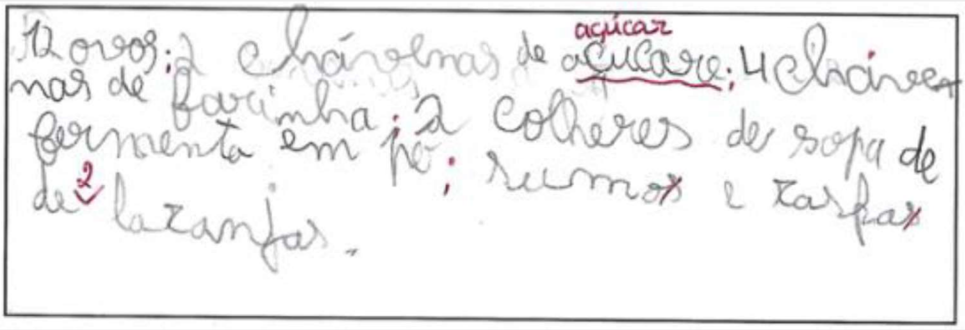


Figure 3. Group 1 Solution.</td></tr>
<tr><td>Group 2</td><td>Intern Teacher: What are you going to do? Explain your reasoning.

A Student: I think for 8 people, it should be one more than it is. Instead of 6, it's 12 eggs.

A Student: I don't think that's right. That would be for 1 extra person.

A Student: If it's for 8 people, let's make it for 4 more. Add 4 more to everything.



A Student: Okay, so instead of 6 eggs, we add another 6. Instead of 1 cup, it's 2...

Figure 4. Group 2 Solution.</td></tr>
<tr><td>Group 4</td><td>A Student: Add baking powder, it will make it rise.</td></tr>
</table>

	A Student: I don't know how to draw baking powder. Intern Teacher: What do you need to do? A Student: Make two cakes. A Student: If one cake serves four people. Another cake will serve eight. A Student: I was going to make one cake, but with double the size. Since not everyone agreed, we decided to make two cakes.

Figure 5. Group 4 Solution.

The last task "What ingredients do these cakes have in common?" raised some questions about the meaning of the term “in common”. Once they understood its meaning, they easily resolved the question. However, there were groups that mentioned the oven as an ingredient, as we highlight below.

Group	Reasoning
Group 3	Intern Teacher: What does "in common" mean? A Student: It means having the same thing.
Group 4	A Student: Flour, baking powder, and oven. Intern Teacher: Did you read the question properly? It's about ingredients! A Student: Eggs, white sugar, flour, baking powder, the oven.

In this task, the dimension of Computational Thinking, Pattern Recognition, is evident, as the students recognized and identified the ingredients that are common among the cakes that could be made using the images on the educational mat.

The task "What is the path you take to get the ingredients for your cake? Don’t forget the cake has to go in the oven." generated some discussions among the students, both individually and with their peers. A majority of the class initially struggled to understand what was being requested. After some simpler guiding questions, the students deconstructed the task and realized they had to envision the path to make the cake. Some groups first represented the path using arrows on the exploration sheet and then filled in the spaces. Others chose to start by writing in the spaces and then drawing the arrows on the mat represented on the exploration sheet. Subsequently, each group easily carried out the envisioned path, but this time with the robot, and it was at this moment that some realized they were missing steps to make the cake. With this task, the students were able to develop algorithmic thinking by creating an algorithm, although the recipe itself is one, to respond to the task.

The task "What other cake can you make? With what ingredients?" was easy for all groups, as we analysed in the evidence. The groups immediately began identifying various cakes that could be made and their respective ingredients. Then, they discussed and decided on the final answer, developing skills and competencies inherent to group work. Since the students were able to structure what was asked of them into less complex questions, they developed the Decomposition dimension.

Regarding the task "Do you think you could make other cakes with the ingredients on the mat? If so, which ones?" it allowed the students to analyse the reasoning they had in the previous question and to test and optimize the final answer, developing the Debugging dimension.

In session 3, given that the focus was the mathematical theme of Data and Probability, and starting from the previously mentioned task, the students listed the various types of cakes that could be made. As the students identified these cakes, one of the trainee teachers was recording on the board and constructing the table that was intended to organize the data to find out which cake they would like to try. The table was built based on the model used by the class's main teacher, and it was organized into three columns: type of cake, number of students, and absolute frequency. Knowing they had to answer the question "The cake I would like to try...", each student, respecting the classroom rules, went to the board to register that cake with a vertical stroke. Each vertical stroke corresponded to one vote. Then, without much difficulty, they quickly identified the absolute frequency corresponding to each type of cake. To systematize the learning related to this mathematical theme, each student recorded it in their daily notebook (Figure 7). According to the absolute frequency table, the students easily identified the cake with the most votes, which was the apple cake. To conclude the session, and also as a way to systematize the three sessions, the cake was made with the class. Each student, maintaining classroom rules, mentioned the steps following the recipe preparation mode example (Appendix 1– Exploration Sheet: Part 1) so that one of the trainee teachers could make the cake.

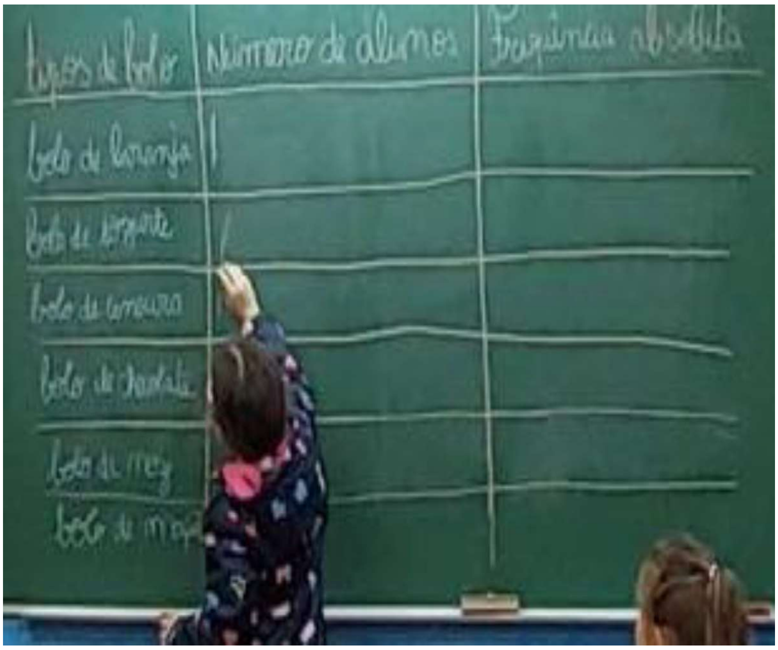
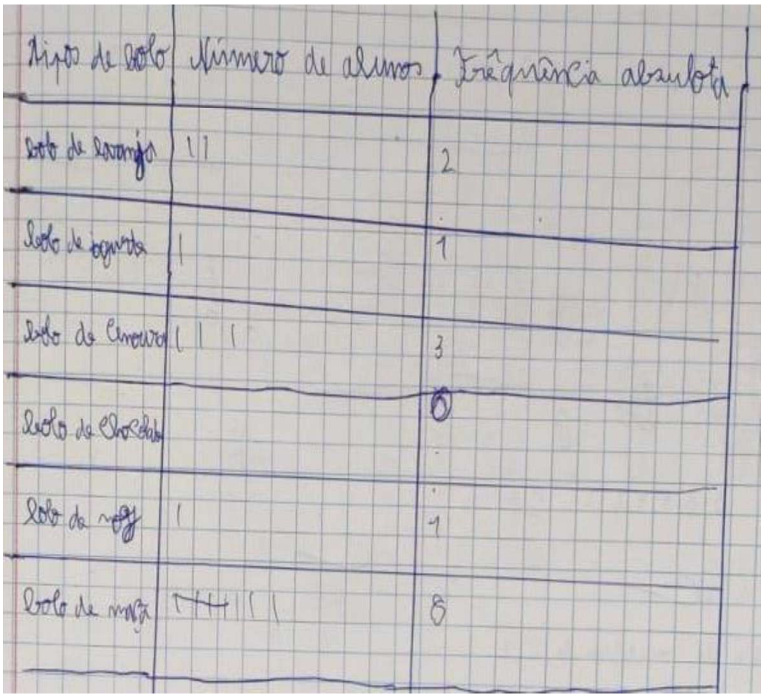


Image 21. Filling in the table of absolute frequencies.



Tipo de bolo	Número de alunos	Frequência absoluta
Bolo de laranja	||	2
Bolo de iogurte	|	1
Bolo de cenoura	|||	3
Bolo de chocolate		0
Bolo de noz	|	1
Bolo de maçã	~~||||~~ |||	8

Image 22. Written record of the table of absolute frequencies "The cake I'd like to taste...".

During the tasks, as we moved around the groups, we noticed that some students were not collaborating. In this regard, we felt the need to encourage the students to actively participate in solving the tasks and promote true group work where the sharing of ideas and mutual respect prevail. After analysing all the evidence, we realized that the groups were dispersing more often than we had observed.

In the discussion phase of the tasks, the students became aware of different solutions, questioned themselves, and were encouraged to compare with what they had written on their exploration sheet. Thus, the discussions were very enriching not only for the students but also for us, as they positively exceeded our expectations.

Conclusions and Implications

During the training of the trainee teachers, they had not worked with the Exploratory Teaching model. As students in teacher training, they initially found it difficult to understand this teaching model. During their training in the curricular units of Educational Practice II, Mathematics II, and Mathematics Didactics, they came to understand how to plan using the exploratory teaching model as well as the development of Computational Thinking dimensions.

The opportunity they had to engage with the Exploratory Teaching model, as students and trainee teachers, was enriching for their training. Their contributions go beyond the development of the five dimensions of Computational Thinking, as the implementation of this teaching model also allows the development of competencies listed in the Profile of Students at the End of Mandatory Schooling.

In this sense, the introduction of the Exploratory Teaching model in the 2nd-grade class was a positive, enriching, and challenging experience. The trainee teachers have continued to implement this teaching model, and it is evident that the students have been developing competencies and skills such as autonomy; critical and creative thinking; reasoning and problem-solving; expressing and discussing mathematical ideas. To develop the various tasks presented, it was necessary for the trainee teachers to know their internship context, understand the knowledge that the class already mastered with more or less ease, and know their interests. Based on these premises, tasks were developed that were appropriate to the specifics of the class. They understood that it is possible to develop any of the dimensions of Computational Thinking through adaptations to different contexts, considering the internship class and its specifics. Thus, there was a significant evolution in terms of time management in carrying out tasks, interpretation of tasks, cooperation and collaboration in groups, and also the complexity of the reasoning presented.

The teacher, in this teaching model, is just a mediator in knowledge acquisition. Unlike traditional teaching, where the teacher has a transmissive role, in the Exploratory Teaching model, they only accompany students, systematizing at the end what they have discovered. Throughout the process, in which the student engages with the objective of acquiring knowledge, the teacher asks guiding questions to facilitate their reasoning. In addition to the guiding questions, they also provide small debates among the students, allowing them to develop communicative ability and the other competencies already mentioned. The trainee teachers became aware that a teacher should know the curriculum and adapt it to their context, defining concrete and realistic learning objectives and competencies.

In summary, the implementation of this Exploratory Teaching model to develop the dimensions of Computational Thinking allows for the promotion of many more capabilities and competencies than the trainee teachers initially expected. Through this model, and interdisciplinarity, students not only are at the centre of building their knowledge but also develop competencies and capabilities that will accompany them throughout life. The cognitive challenge promoted throughout the four phases of the Exploratory Teaching model makes students curious and leads them to seek answers to consolidate their knowledge.

Acknowledgments

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Appendices

Appendix 1 – Exploration Sheet

Exploration Sheet – "Let's Explore"

For this activity, we will need:

- Six eggs
- One cup of sugar
- Two cups of flour
- One tablespoon of baking powder
- Juice and zest of one orange

Preparation:

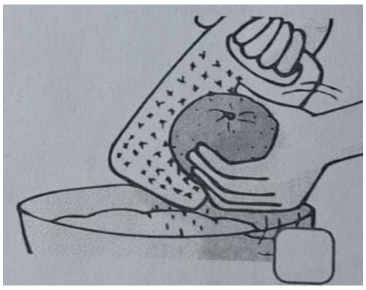
Separate the egg yolks from the egg whites.
Beat the egg yolks with the sugar.
Add the orange juice and flour. Continue to beat.
Add the orange zest and baking powder. Continue to beat.
Beat the egg whites until stiff and fold them into the mixture.
Bake in the oven at 180°C for 40 minutes.

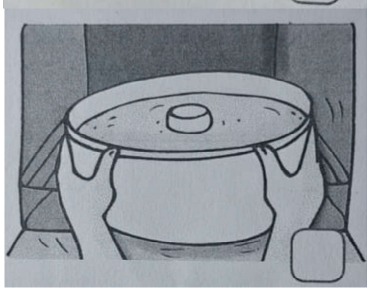
Part 1

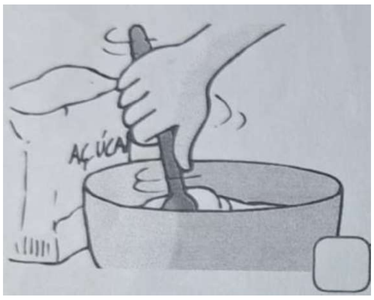
1. What type of text does it seem to be?

Answer: ____

2. Observe the images and arrange them in the order of the preparation steps, identifying each image with its respective number.





3. List all the elements you think are important for making a cake.

Answer: ____

4. This recipe is for 4 people. If you want to make it for 8 people, what do you need to do?

Answer: ____

Part 2

1. What did you discover when exploring the SuperDoc robot?

1st discovery: ____

2nd discovery: ____

3rd discovery: ____

2. What is the path you take to gather the ingredients for your cake? [Apply the number of steps you identify, and do not forget that the cake needs to go into the oven.]