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Development of computational thinking and statistical literacy through applets of the Hypatiamat platform

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Abstract

In Portugal, in primary school, problem-solving and computational thinking (CT) are fundamental for students' academic success. This article aims to assess the influence of the applets "Stem-and-leaf plot" and "Data analysis – Mode, mean, and median" from the Hypatiamat platform (HP) on the understanding of statistical concepts and on the development of the five dimensions of CT in 4th-grade students (aged between 9 and 10 years). This article adopts a mixed-methods approach, with an interpretative nature and an action research design. A total of 24 students participated from a 4th-grade primary school at a Portuguese school. The intervention comprised four structured sessions using exploratory teaching practices (ETP). Data collection included pre- and post-intervention tasks, assessed through the levels of knowledge and performance by task. The results indicate that the use of the applets "Stem-and-leaf plot" and "Data analysis – Mode, mean, and median" from the HP, through ETP, promoted students' learning and the development of the dimensions of CT. The main contribution of this study is the presentation of an innovative didactic proposal that links the development of CT with the acquisition of mathematical knowledge in the topic of data and probability, using the HP within the framework of ETP.

Keywords: primary school, computational thinking, statistical literacy, exploratory teaching practices, Hypatiamat platform

INTRODUCTION

In primary school it is essential to highlight and clarify the different strategies used in problem-solving, particularly those related to the development of computational thinking (CT) (Ministry of Education (ME), 2021; Rodrigues et al., 2026a). This concept aims to equip students with the ability to solve problems in a structured way, namely by decomposing them into simpler parts and constructing algorithms that lead to a solution (Polat et al., 2025; Wing, 2006). The development of the various dimensions of CT is thus becoming increasingly relevant to the integral development process of primary school students, insofar as it promotes learning focused on understanding processes, which are fundamental for solving everyday challenges (Voon et al., 2022).

The development of competencies such as CT has been associated with the integration of digital artefacts in the classroom, resources that play a significant role in knowledge construction and in the development of computational skills (Lee et al., 2022; Romero-Tena et al., 2023). Furthermore, the appropriate use of these resources can foster a positive attitude towards

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Contribution to the literature

- This study provides empirical evidence that integrating applets within an exploratory teaching practice (ETP) approach can simultaneously enhance primary students' statistical literacy and CT.
- The findings extend previous research by presenting a replicable didactic proposal that meaningfully combines digital technologies, ETP, and CT in primary education.
- These results provide practical guidance for researchers and teachers seeking to design technology-enhanced mathematics learning environments that foster both mathematical knowledge and 21st century competencies.

mathematics, enabling students to develop more meaningful learning (Martins et al., 2018). Among the available digital artefacts, the Hypatiamat platform (HP) stands out, supporting the learning of topics such as data organization and analysis (Pinto et al., 2022), allowing students to explore and interpret graphical representations and thus contributing to the development of statistical literacy (ME, 2021).

Carvalho et al. (2024) further highlight the contribution of ETP to the development of CT, the systematization of mathematical concepts, and the acquisition of fundamental skills in children. ETP has proved particularly beneficial for students' learning, as they promote the active and meaningful construction of knowledge (Freitas et al., 2025; Ponte, 2005). This approach enables students to learn mathematical concepts through discussion and the sharing of ideas within the group, fostering the development of skills such as mathematical reasoning, problem-solving, and communication in mathematical contexts (Canavarro et al., 2012; Rodrigues et al., 2026b). Several studies have reported their positive effects on mathematics learning (Carvalho et al., 2024; Francisco et al., 2025; Freitas et al., 2023). However, the articulation between these practices and the development of CT dimensions in the context of statistical content remains underexplored.

In Portugal, the mathematics curriculum for the 4th-grade of primary school, within the topic of data and probability (ME, 2021), includes the formulation of statistical questions, data collection and organization, graphical representations, and data interpretation. However, significant difficulties persist in relation to the "Stem-and-leaf plot", particularly in assigning and justifying the title, identifying extreme values, and interpreting the data (Pereira, 2013). The systematic review conducted by Ye et al. (2023) also identifies, as a gap in CT research, the need for studies examining how this mathematical ability can be developed in articulation with mathematical learning, particularly in the domain of statistics. Santaengracia et al. (2026) similarly highlights a significant gap in the description of instructional practices and models that promote the development of CT in the early years of schooling. In this context, it is relevant to investigate didactic proposals that operationalize this articulation in specific learning contexts by intentionally integrating the development of different CT dimensions with the learning of specific mathematical content. The present study addresses this need by combining digital artefacts from the HP with ETP to teach content within the data and probability topic of the Portuguese primary school mathematics curriculum (ME, 2021).

Accordingly, this article aims to assess the influence of the use of these applets on students' learning regarding the "Stem-and-leaf plot" and on the development of CT. To this end, the following research question was formulated: Does the use of the applets "Stem-and-leaf plot" and "Data analysis – Mode, mean, and median" from the HP promote, in 4th-grade of primary school students, learning related to the "Stem-and-leaf plot" graphical representation while simultaneously fostering the development of CT?

The main contribution of this study lies in the presentation and evaluation of a didactic proposal that integrates the development of CT with the learning of statistical content in primary school, using digital artefacts from the HP within the context of ETP.

THEORETICAL BACKGROUND

Computational Thinking in the Educational Context

CT has gained increasing importance in mathematics curricula across various countries (Nordby et al., 2022; Rodrigues et al., 2025). Papert (1980) was a pioneer in addressing this competence, highlighting the relevance of integrating technology and computational concepts into the educational context. The author argued that these tools provide children with new learning opportunities, promoting both cognitive and emotional development (Papert, 1980). Later, Wing (2006) further developed the study of CT and emphasized the importance of its integration into education, defining it as the process of recognizing aspects of computation in everyday life and adopting tools and methods to reflect on artificial, natural, and social procedures. This perspective underscores the importance of generalizing ways of thinking from computer science (Albuquerque, 2021), positioning CT as an essential competence for all individuals, not only for professionals in the field of computing (Wing, 2006).

Although CT has its roots in computer science, it constitutes an essential competence for solving a wide range of complex problems in a structured and consistent manner across multiple disciplines (Moschella & Basso, 2020; Rodrigues et al., 2025). Nevertheless, it is within mathematics that CT has assumed a particularly prominent role, being progressively integrated into the curricula of several countries (Rodrigues et al., 2025). According to Oliveira (2019), CT is characterized as an activity involving processes of conception, reflection, abstraction, and expression. Given its connection to pattern recognition and problem-solving, this competence is often compared to solving a puzzle (Loureiro et al., 2020), which requires a set of skills that, in Portugal, have been incorporated into the essential learnings for mathematics (ME, 2021).

Dimensions of Computational Thinking in Solving Mathematical Tasks

Although there is no single, universally agreed-upon definition of CT, nor of its constituent dimensions (Carvalho et al., 2024; Haşlaman et al., 2024; Rodrigues et al., 2022), CT is generally understood as a set of skills required for problem-solving (Ausiku & Matthee, 2021; Yun & Crippen, 2025). The literature and the national mathematics curriculum identify five key capacities to be developed: abstraction, decomposition, algorithmic thinking, debugging, and pattern recognition (Francisco et al., 2025; ME, 2021).

Abstraction can be defined as the ability to select the most relevant information, thereby reducing the amount of presented information and highlighting the key details required to solve a given task (Albuquerque, 2021; Rodrigues et al., 2025). According to Candeias et al. (2025), this dimension can be promoted through tasks that encourage students to focus on the essential elements of the problem.

Decomposition, in turn, involves breaking down a task into smaller parts, selecting the essential aspects to address, understanding the structure of a given task, and how these smaller components are interconnected (Angeli & Georgiou, 2023; Espadeiro, 2022). To foster the development of this dimension, it is necessary to provide students with contexts in which they can segment problems into smaller parts, thereby facilitating understanding, organization, and resolution (Chaabi et al., 2025).

Algorithmic thinking enables the development of a finite sequence of steps that lead to the solution of a task, with these procedures potentially being applied to other tasks (Brackmann, 2017; Voon et al., 2022; Zeng et al., 2023). Yun and Crippen (2025) state that this competence develops when students are faced with challenges that require the sequential organization of steps needed to reach a solution.

The dimension of debugging implies that students can identify errors, inaccuracies, or aspects to improve in their strategies, with the aim of refining their chosen solution (Albuquerque, 2021; Macann & Hartnett, 2025). Gao and Hew (2022) argue that this is generally the dimension in which students experience the greatest difficulties, as they are not familiar with this process.

Pattern recognition refers to the ability to identify patterns in the resolution of a task and to apply them to the solution of similar tasks (Hsu & Tsai, 2024; Lee et al., 2022). To promote this dimension, it is essential that students are encouraged to detect regularities and similarities across different tasks, enabling them to apply previously acquired strategies in new situations (Palop et al., 2025).

The Role of Computational Thinking and Technology in 21st Century Skills

In contemporary 21st century society, the cognitive skills required for citizenship go beyond traditional abilities such as reading, writing, and numeracy, encompassing the capacity to describe, explain, and act within complex contexts (Conforto et al., 2018; Rodrigues et al., 2025). CT significantly contributes to the development of the skills highlighted by the World Economic Forum (2016) for future professionals, including complex problem-solving, critical thinking, creativity, cognitive flexibility, as well as judgment and decision-making abilities (Rodrigues et al., 2025).

CT fosters logical reasoning, as it has strong potential for organising ideas, reflecting the ability to understand issues objectively. The integration of CT with the content of different school subjects, supported by technology, has high potential to promote students' cognitive development, equipping them with tools that enable problem-solving (ME, 2021; Schlögl et al., 2017).

CT also promotes the development of creativity, as students are encouraged to explore different ways of solving a problem. By granting students greater autonomy, this process requires more active involvement in constructing their own learning, contributing to more meaningful learning experiences (Conforto et al., 2018; Rodrigues et al., 2025).

According to studies by Bobsin et al. (2020) and Rodriguez et al. (2015), educational contexts have increasingly emphasized CT, promoting new ways for students to engage with and deepen their understanding of scientific knowledge and to develop cognitive skills. It is therefore essential to implement teaching and learning processes that foster the development of CT, as these are indispensable practices in mathematics. Moreover, individuals with well-developed cognitive abilities for problem-solving tend to be better prepared for current and future professions (Almeida et al., 2021; Brackmann, 2017; ME, 2021).

MATERIALS AND METHODS

Study Design

This study is of a mixed nature (Creswell & Plano Clark, 2018), interpretative (Amado, 2017) and action research design (Bogdan & Biklen, 2013). Mixed-methods research combines data collection and analysis using methods and instruments typical of both quantitative and qualitative research (Cohen et al., 2018; Creswell, 2014; Creswell & Creswell, 2018). The qualitative component focused on an exploratory analysis of the tasks completed by the students at the pre- and post-intervention stages, with the aim of identifying changes in their solutions. The quantitative component aimed to analyze and compare the levels of knowledge (LK) defined for the specific task objectives and students' performance by task (PT) before and after the intervention, as well as to determine the statistical significance of the observed differences. The quantitative and qualitative data were analyzed in a complementary manner, allowing the statistical results to be integrated with evidence from students' work and thereby providing a more comprehensive understanding of their learning in relation to CT and statistical literacy.

An action research design was adopted due to its cyclical and reflective nature, allowing the pedagogical intervention to be articulated with the systematic analysis of practice and the evidence collected to inform and adjust subsequent stages of the process (Vilelas, 2020). Accordingly, the action plan was not conceived as a rigid structure, and specific adjustments were introduced throughout the intervention based on the analysis of the evidence collected in each session. These included discontinuing the guide initially provided to access the HP after it became evident that students were able to complete this procedure autonomously.

Participants

The sample of this study consisted of a 4th-grade of primary school in Coimbra, Portugal. The class comprised 24 students, aged between 9 and 10 years, including 16 females and 8 males. The data were collected as part of an internship carried out by a pre-service teacher in a teacher training course at a Portuguese higher education institution. During the pedagogical intervention sessions, students were organized into nine pairs and two groups of three, in accordance with the principles of the zone of proximal development (ZPD) (Vygotsky, 1980). It is important to note that the pre-service teacher, as she was undertaking her curricular practicum with the participating class, was directly involved in the educational context under investigation. She participated in identifying the problem, designing and planning the intervention, and implementing it, thus assuming the dual role of pre-service teacher and researcher. The classroom teacher was also involved throughout the different stages of the study's design, planning, and implementation. Her involvement began with the identification of the students' difficulties that gave rise to the study and extended to the development and validation of the data collection instruments and their respective analysis criteria, as well as the planning of all aspects related to the implemented sessions. During the intervention, she attended all sessions in a supervisory role. Finally, the pre-service teacher's supervisors were involved throughout the different stages of the process, contributing to the design, supervision, and validation of the procedures adopted. Throughout the manuscript, the term pre-service teacher refers to the trainee who conducted the intervention and assumed the role of researcher; classroom teacher refers to the teacher responsible for the participating class; and supervisors refers to the faculty members from the higher education institution who supervised the study.

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 (regulation [EU] 2016/679 of the European Parliament and Council of 27 April). These measures underscore the study's commitment to transparency, integrity, and adherence to the highest ethical and legal standards.

Pedagogical Intervention

The study was conducted between February 26 and March 20, 2024. The problem was identified through classroom observation and further informed by the administration of the pre-intervention tasks on February 26. These tasks served a formative assessment purpose, allowing the identification and mapping of students' difficulties regarding the mathematical knowledge and CT dimensions under study. Based on the difficulties identified, an action plan comprising four sessions was designed. It involved the implementation of tasks specifically designed to address these difficulties and integrated the use of the "Stem-and-leaf plot" and "Data analysis – Mode, mean, and median" applets from the HP, considering the potential of the platform's digital artefacts to support students' learning (Escaroupa, 2023; Freitas, 2024; Gomes, 2023). The tasks were carried out in

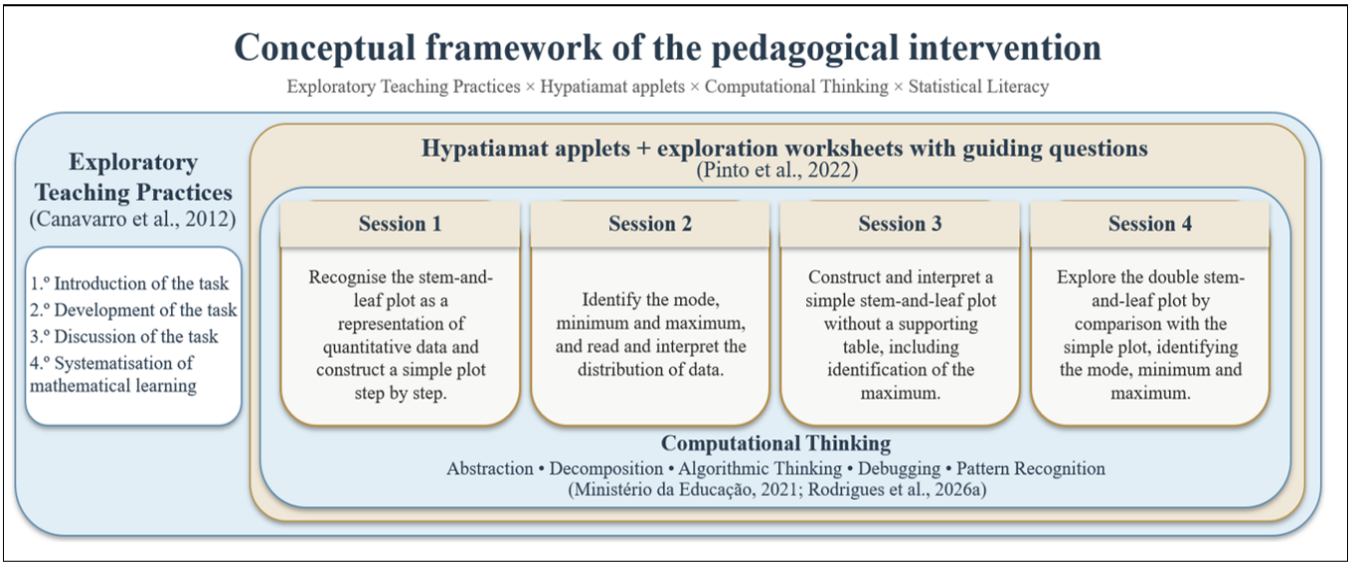


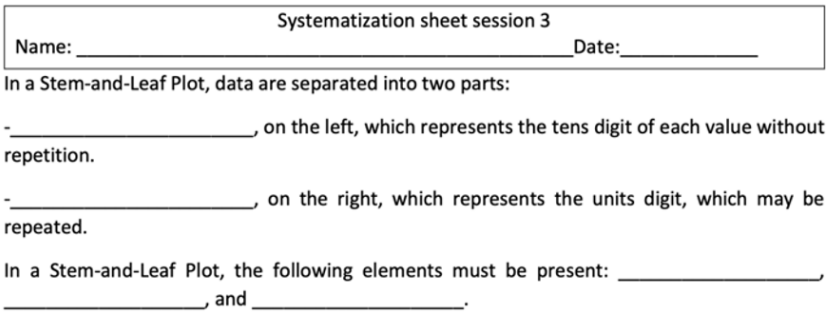
Figure 1. Conceptual framework of the pedagogical intervention (the authors' own work)



Figure 2. Example of a guide for access and exploration of the HP (the authors' own work)

small groups using exploration sheets that incorporated the frames explored on the HP and guiding questions designed to promote the five dimensions of CT. Following the four sessions, the post-intervention phase took place on March 20, 2024, with the administration of the final tasks, followed by reflection on and interpretation of the data collected. **Figure 1** presents a Conceptual framework that synthesizes the pedagogical intervention and outlines the objectives of each of the four sessions, as well as their articulation with ETP, the HP, and CT.

The pedagogical intervention was implemented between March 14 and 19, 2024, over four sessions. Session 1 and session 2 were planned to last 120 minutes, whereas session 3 and session 4 were planned to last 90 minutes. All sessions were structured according to ETP (Canavarro et al., 2012), comprising four phases: introduction of the task, development of the task, discussion of the task, and systematization of mathematical learning. In session 1 and session 2, 10, 50, 50, and 10 minutes were allocated to each of these phases, respectively, whereas in session 3 and session 4, 15, 30, 30, and 15 minutes were allocated, respectively. During the sessions, students were organized into nine pairs and two groups of three, in accordance with the principles of the ZPD, as proposed by Vygotsky (1980). When forming the groups, students' levels of development were considered, grouping students with similar, though not identical, levels. Each group was provided with a computer and an exploration sheet. At the beginning of each session, students entered the classroom, went to their assigned workstations, turned on the computers, and initiated screen recording using Apowersoft software (Apowersoft free online audio recorder). They then accessed the HP and logged in. Access to the platform was carried out autonomously, supported by a Hypatiamat access guide (**Figure 2**).


Systematization sheet session 3

Name: _____Date:_____

In a Stem-and-Leaf Plot, data are separated into two parts:

-_____, on the left, which represents the tens digit of each value without repetition.

-_____, on the right, which represents the units digit, which may be repeated.

In a Stem-and-Leaf Plot, the following elements must be present: _____, _____, and _____.

Figure 3. Example of the systematization sheet from session 3 (the authors' own work)

This process was also supported by the researcher, who projected the procedures on the board. Following the reflective approach of the action research design, procedures were reviewed between sessions considering the evidence gathered during the intervention. For example, once students demonstrated that they could access the HP autonomously, the access guide was no longer provided in subsequent sessions.

In the first session, the aim was for students to understand that a "Stem-and-leaf plot" is a type of representation of quantitative data consisting of a stem and leaves. It was also intended that students would be able to construct, step by step, a "Stem-and-leaf plot" and interpret and analyze the data. To support this, the graph construction task guided students by providing a table to assist in the construction process. The second session aimed at enabling students to identify the mode, minimum, and maximum in a set of discrete quantitative data, specifically within a "Stem-and-leaf plot". In the third session, students constructed and interpreted data using a "Stem-and-leaf plot". However, in this case, no supporting table was provided for the construction, thereby increasing the level of difficulty of the task. Finally, the fourth session aimed to explore the double "Stem-and-leaf plot" through comparison with the "Stem-and-leaf plot". Students constructed a double "Stem-and-leaf plot". During the task introduction phase, the pre-service teacher communicated the objectives of the session and presented the tasks that students were expected to complete. Additionally, students were alerted to potential points that might raise difficulties during task development. At this stage, it was ensured that all pairs clearly understood the instructions, while maintaining an environment conducive to concentration and silence. Students were also given the opportunity to clarify any doubts. Finally, the pre-service teacher defined the time allocated for the task development phase (Anghileri, 2006). During the task development phase, the pre-service teacher circulated among the groups while students worked on the tasks using both the applet and the exploration sheets. The aim was to ensure the active involvement of all group members, adopting a guided questioning approach rather than providing direct answers to students' questions (Canavarro et al., 2012). This approach sought to avoid reducing the cognitive demand of the tasks, as highlighted by Stein and Smith (1998). During this phase, the pre-service teacher also took notes on the different groups' solutions in preparation for the subsequent discussion phase. During the task discussion phase, the pre-service teacher managed students' participation and interaction, promoting mathematical quality, understanding, and the comparison of different solutions, focusing on key mathematical ideas (Canavarro et al., 2012). At this stage, students were instructed to make notes on the exploration sheets using a pen, without erasing or adding anything in pencil. Finally, during the systematization phase, the mathematical concepts addressed in the lesson were summarized (Canavarro et al., 2012). Each student was provided with a systematization worksheet (**Figure 3**). The pre-service teacher first read the questions from the systematization sheets, which were then collectively analyzed and subsequently recorded individually by the students. At the same time, a PowerPoint presentation prepared by the pre-service teacher was projected, displaying the worksheet questions followed by their corresponding answers.

The exploration sheets used during the sessions, as well as during the pre- and post-intervention phases, were developed by the research team (the pre-service teacher and the two supervisors) and the classroom teacher and validated by five independent researchers. These researchers are experts in mathematics education who work directly in initial teacher training at both national and international levels and have experience in mathematics didactics, particularly in the development of CT. The validation process involved an independent review of the tasks by each expert, considering their relevance, clarity, and alignment with the defined objectives. Based on the feedback and suggestions provided, the tasks were subsequently revised and refined, resulting in their final version.

Data Collection

Data collection took place between February and March 2024, within the scope of the curricular unit educational practice in primary school. The data were collected by the researcher (the pre-service teacher) in

Table 1. Research sessions

Pre-intervention phase	Intervention phase				Post-intervention phase
Initial task	Session 1	Session 2	Session 3	Session 4	Final task
26 February	4 March	11 March	12 March	19 March	20 March

Leonor celebrated her birthday with friends and family. She asked each guest for their height in centimeters and recorded it: 160, 137, 164, 135, 157, 149, 157, 154, 138, 149, 138, 175, 178, 194, 157, 148, 136, 153.

In the following month, Bárbara also held her birthday party and recorded the heights of her guests: 172, 144, 156, 138, 158, 151, 153, 148, 145, 154, 139, 157, 130, 159, 153, 163, 161, 171.

1. Organize the data into a double "Stem-and-leaf plot". Describe the steps you followed to construct the double "Stem-and-leaf plot", explaining your reasoning using words, diagrams, or drawings.
2. Identify the information in the problem statement that was essential for constructing the double "Stem-and-leaf plot".
3. Check whether you constructed the double "Stem-and-leaf plot" correctly in task 1. Identify all the elements that must be included in a double "Stem-and-leaf plot". Explain your thought process using words, diagrams, or drawings.

Figure 4. Pre-intervention phase (the authors' own work)

The travel times recorded by the teachers in group 1 are presented below: 60, 90, 135, 60, 148, 60, 45, 75, 30, 50, 130, 148, 100, 120, 157, 57, 135, 153.

The travel times recorded by the teachers in group 2 are presented below: 180, 120, 150, 110, 165, 157, 175, 145, 156, 115, 148, 65, 130, 138, 105, 180, 140, 60.

1. Organize the data into a double "Stem-and-leaf plot". Describe the steps you followed to construct the double "Stem-and-leaf plot".
2. Identify the information in the problem statement that was essential for constructing the double "Stem-and-leaf plot".
3. Check whether you constructed the double "Stem-and-leaf plot" correctly in task 1. Identify all the elements that must be included in a double "Stem-and-leaf plot". Explain your thought process using words, diagrams, or drawings.

Figure 5. Post-intervention phase (the authors' own work)

Table 2. Criteria for classifying the LK (criteria adapted from Freitas, 2024)

Level 1 (L1)	Level 2 (L2)	Level 3 (L3)	Level 4 (L4)
The solution shows no understanding of the mathematical concepts addressed or presents no attempt at solving the task.	The solution shows poorly structured knowledge of the mathematical concepts in question and contains several errors.	The solution shows some understanding of the mathematical concepts addressed, although it contains some errors.	The solution shows full mastery of the mathematical concepts applied in the task.

three distinct stages: the pre-intervention phase, the intervention phase, and the post-intervention phase (**Table 1**).

Each intervention session lasted 120 minutes for session 1 and session 2, and 90 minutes for session 3 and session 4.

In the pre- and post-intervention phases, initial and final tasks were administered (**Figure 4** and **Figure 5**) with the objective of identifying students' difficulties regarding the concept of the double "Stem-and-leaf plot", as well as the different dimensions of CT. Although the broader study included additional tasks, for the purposes of the present article, the analysis focused on those that explicitly involved the mobilization of CT dimensions in articulation with the mathematical knowledge under study.

Task 1 involved the construction and organization of data in a double "Stem-and-leaf plot". Task 2 focused on identifying the essential information required for the construction of the double "Stem-and-leaf plot". Task 3 involved verifying (debugging) the mandatory elements and the correctness of the double "Stem-and-leaf plot".

The assessment of the tasks carried out during the pre-intervention and post-intervention phases was conducted based on a criterion structured into four LK (**Table 2**) and specific objectives (**Table 3**), developed by the research team, considering the mathematical knowledge involved in the tasks. These criteria, like the tasks included in the exploration sheets, were validated by five independent researchers with expertise in mathematics education. Each researcher independently examined the criteria and provided feedback and suggestions, which were subsequently reviewed by the research team and incorporated into the revision process, resulting in the final version. The use of criteria aimed to identify students' difficulties to design an action plan based on those difficulties (Brookhart & Chen, 2015).

According to Panadero et al. (2023), the use of specific criteria increases the reliability of assessment. This evaluation also aimed to analyze students' progress before and after the intervention (Petkov & Petkova, 2006).

Table 3. Descriptors of the LK by specific task objectives (criteria adapted from Freitas, 2024)

Task 1		Specific objectives			
		Mathematical knowledge	Mathematical skills – CT dimension		
	LK	Represent quantitative data sets on the same variable using double "Stem-and-leaf plot", including source, title, and legend.	Pattern recognition – Recognizing patterns in the process of constructing a double "Stem-and-leaf plot": identifying that, in all data, the digits in the tens place must be separated from those representing units, with the tens placed in the stem (without repetition) and the units in the leaves (with repetition when values are repeated); and recognizing that only one stem needs to be constructed, as the tens are common to the data from both sets.	Algorithmic thinking – Describing and ordering the steps involved in constructing a double "Stem-and-leaf plot", which should include: separating the tens digits from all data and placing them in the stem in ascending order from top to bottom; organizing the leaves (units digits of all data) on the left side of the stem for one data set and on the right side for the other data set, in ascending order from the stem and aligned with the row corresponding to the tens value of each data point; and including the legend and title.	Decomposition – Breaking down the construction of a double "Stem-and-leaf plot" into simpler tasks: organizing the data into rows according to the tens (data with the same tens in the same row) and in ascending order; separating the tens digits from the units digits and placing them in the stem in ascending order from top to bottom; organizing the leaves in ascending order in the appropriate rows.
	1	No solution is provided, or the solution presented is not related to the task.			
	2	Constructs a double "Stem-and-leaf plot"; however, it contains numerous errors that indicate a lack of understanding of how it should be constructed: the leaves are not arranged in ascending order, and the stems are not organized in ascending order.	Demonstrates recognition that the ten digits should be separated from the units' digits; however, the solution is not completed.	Describes one of the steps required to construct a double "Stem-and-leaf plot".	Carries out one of the tasks required to construct a double "Stem-and-leaf plot".
	3	Constructs a double "Stem-and-leaf plot"; however, it does not include a title or a legend.	Separates the tens digits from the units' digits, placing the tens in the stem and the units in the leaves; however, fails to recognize that only one stem is needed, constructing two double "Stem-and-leaf plot".	Describes two of the steps required to construct a double "Stem-and-leaf plot".	Carries out two of the tasks required to construct a double "Stem-and-leaf plot".
	4	Correctly construct a double "Stem-and-leaf plot".	Correctly constructs a double "Stem-and-leaf plot" (demonstrating recognition that the tens digits are common to both data sets).	Describes the three steps required to construct a double "Stem-and-leaf plot".	Executes the three tasks required to construct a double "Stem-and-leaf plot".
Task 2	LK	Specific objectives: Mathematical skills – CT dimension Abstraction – Identifying the three essential pieces of information in the task.			
	1	No solution is provided or none of the essential information required to solve the task is identified.			
	2	Identifies one of the essential pieces of information required to solve the task.			
	3	Identifies two of the essential pieces of information required to solve the task.			
	4	Identifies three of the essential pieces of information required to solve the task.			
Task 3		Specific objectives			
	LK	Mathematical knowledge	Mathematical skills – CT dimension		
		Identify the elements of a double "Stem-and-leaf plot": source, title, and legend.	Debugging – Verify whether the double "Stem-and-leaf plot" is constructed correctly.		
	1	No solution is provided, or the solution presented is not related to the task.			
	2	Identifies one of the elements of a double "Stem-and-leaf plot".	Indicates that the double "Stem-and-leaf plot" is correctly constructed because it includes one of the three required elements.		
	3	Identifies two of the elements of a double "Stem-and-leaf plot".	Indicates that the double "Stem-and-leaf plot" is correctly constructed because it includes two of the three required elements.		
	4	Identifies three of the elements of a double "Stem-and-leaf plot".	Indicates that the double "Stem-and-leaf plot" is correctly constructed because it includes three of the three required elements.		

To assess the solutions presented for the tasks in the pre-intervention and post-intervention phases, a set of descriptors corresponding to each LK was developed. These descriptors were defined based on the specific objectives established for each task (**Table 3**) and adapted from the proposal by Freitas (2024).

Table 4. Percentage values assigned to each LK by task objective

Tasks	Percentage values (%)	Levels	Objective 1	Objective 2	Objective 3	Objective 4
1	35	1	0%	0%	0%	0%
		2	5%	1%	1%	1%
		3	15%	4%	4%	4%
		4	20%	5%	5%	5%
2	15	1	0%			
		2	4%			
		3	11%			
		4	15%			
3	15	1	0%	0%		
		2	1%	3%		
		3	4%	8%		
		4	5%	10%		

Each proposed solution was analyzed based on the descriptors and the objectives established for each task. Initially, the median was determined for each task individually, and subsequently, the median of these medians was calculated to define each student's global levels of knowledge (GLK) in the pre- and post-intervention phases.

Table 4 presents the percentage values assigned to each task and their corresponding levels. The percentages presented correspond to the weightings originally assigned to the tasks in the assessment instrument, which comprised five tasks with a total weighting of 100%. For the purposes of the present study, only the three tasks selected for analysis were considered, as they allowed the CT dimensions to be explicitly analyzed in articulation with the mathematical knowledge under study, as described in the "data collection" section. Accordingly, the original weightings assigned to these three tasks were retained, together accounting for 65% of the assessment instrument. Students' PT was determined based on the percentage values attributed to each specific objective in each task.

Data Analysis

Qualitative data analysis

An exploratory content analysis of the qualitative data collected at two moments (pre- and post-intervention) was conducted. This type of analysis involves examining participants' responses to identify meaningful information. In this way, the researchers were able to track changes in participants' solutions over time and identify the specific challenges they faced while completing the tasks. This analysis provided evidence of both learning progress and the difficulties experienced by participants throughout the intervention.

The qualitative analysis was further supported by four multimodal narratives (MN), one for each intervention session, constructed from the data collected during implementation, including students' task solutions, audio recordings of group discussions, photographs, and field notes. Following the protocol proposed by Lopes et al. (2018), the MN provided a detailed, self-contained, multimodal, and chronological account of the events occurring during each session. Once constructed, the MN were validated by independent researchers, who verified their adherence to the established protocol.

Quantitative data analysis

Statistical analysis was conducted using descriptive statistics, with the aim of describing students' GLK and PT in the pre- and post-intervention phases. The characterization of GLK and PT was carried out through the calculation of the mean (M) and standard deviation (SD). The determination of a positive or negative trend in GLK was based on assigning level 3 and level 4 as indicative of positive development, while level 1 and level 2 were considered negative.

A paired-samples t-test was applied to compare GLK and PT obtained in the pre- and post-intervention phases, after verifying its normality assumption (Field, 2018; Marôco, 2021). The normality of the dependent variables was assessed using the Shapiro-Wilk test was used (Field, 2018; Marôco, 2021). In cases where normality was not confirmed, skewness analysis was conducted, considering the following condition (Pestana & Gageiro, 2014; Tabachnick et al., 2021):

$$\left|\frac{Skewness\ coefficient}{Standard\ error\ of\ skewness}\right| \leq 1.96. \quad (1)$$

The effect size of the paired-samples t-test was calculated using Cohen's d, with its classification defined as follows (Sawilowsky, 2009): very small ($d < 0.2$), small ($0.2 \leq d < 0.5$), medium ($0.5 \leq d < 0.8$), large ($0.8 \leq d < 1.2$), very large ($1.2 \leq d < 2.0$) and huge ($d \geq 2.0$). Statistical analysis was performed using IBM SPSS Statistics software (version 29, IBM, USA), with a significance level of 5%.

RESULTS

In this section, the results of the study are presented, organized according to students' LK and PT in the pre- and post-intervention phases.

Table 5. Distribution of absolute (n) and relative (%) frequencies of LK by task objective

	Pre-intervention (%(n))				Post-intervention (%(n))			
	Negative		Positive		Negative		Positive	
	L1	L2	L3	L4	L1	L2	L3	L4
T1 O1	33.3% (8)	62.5% (15)	4.2% (1)	0.0% (0)	0.0% (0)	0.0% (0)	41.7% (10)	58.3% (14)
O2	29.2% (7)	4.2% (1)	0.0% (0)	66.7% (16)	0.0% (0)	0.0% (0)	0.0% (0)	100% (24)
O3	66.7% (16)	25.0% (6)	8.3% (2)	0.0% (0)	8.3% (2)	29.2% (7)	45.8% (11)	16.7% (4)
O4	33.3% (8)	0.0% (0)	4.2% (1)	62.5% (15)	0.0% (0)	0.0% (0)	0.0% (0)	100% (24)
T2 O1	45.8% (11)	37.5% (9)	4.2% (1)	12.5% (3)	8.3% (2)	62.5% (15)	12.5% (3)	16.7% (4)
T3 O1	100% (24)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	100% (24)
O2	100% (24)	0.0% (0)	0.0% (0)	0.0% (0)	66.7% (16)	0.0% (0)	4.2% (1)	29.2% (7)

Note. O1: Objective 1; O2: Objective 2; O3: Objective 3; O4: Objective 4

Table 6. Descriptive statistics and pre- and post-intervention comparison of the GLK

	M	SD	t	p	d	Effect size
Pre-intervention	1.979	0.683	-13.736	0.001	2.804	Huge
Post-intervention	3.813	0.247				

This section presents the study results structured around a quantitative analysis (4.1), focusing on the LK and the performance of the 24 students by objective and by task, comparing the pre- and post-intervention phases; and a qualitative analysis (4.2), which examines the work of selected students representing different levels of performance, thereby illustrating the observed progression in the development of CT and in learning related to the organization and interpretation of data in double "Stem-and-leaf plot" throughout the intervention.

Quantitative Results

The quantitative results are organized according to LK by objective for each task and PT, comparing, in both cases, the results obtained by the 24 students in the pre- and post-intervention phases, with the aim of analyzing the changes observed in the development of CT and in learning related to the organization and interpretation of data in double "Stem-and-leaf plot".

Levels of knowledge

Table 5 presents the distribution of absolute and relative frequencies (%) of students' LK by objective for each task in the pre- and post-intervention phases.

Table 5, regarding the objectives defined for task 1, shows that in the pre-intervention phase, for objective 1 (related to representing quantitative data sets using double "Stem-and-leaf plot"), only one student was at level 3, while the remaining students were distributed between level 1 and level 2. For objective 2 (pattern recognition), 66.7% of the students were at level 4, while the remaining students were at negative levels. For objective 3 (algorithmic thinking), 66.7% of the students were at level 1, with the remainder distributed across level 2 and level 3. Regarding objective 4 (decomposition), 62.5% of the students were at level 4, while the remaining students were at level 1 and level 3. In the post-intervention phase, a positive progression is observed in objective 1, as all students reached level 3 and level 4. For objective 2, all students achieved level 4. Regarding objective 3, 37.5% of the students remained at negative levels, while 62.5% reached positive levels.

Finally, for objective 4, all students achieved level 4. Regarding task 2, whose objective was to identify the essential information of the task (abstraction), in the pre-intervention phase, 83.3% of the students were at negative levels and 16.7% at positive levels. In the post-intervention phase, the percentage of students at negative levels decreased to 70.8%, while the percentage at positive levels increased to 29.2%. Finally, regarding task 3, in the pre-intervention phase, for both objective 1 (identifying the elements of a double "Stem-and-leaf plot": source, title, and legend) and objective 2 (debugging dimension: verifying whether the "Stem-and-leaf plot" is correctly constructed), all students were at level 1. In the post-intervention phase, for objective 1, all students reached level 4; for objective 2, 66.7% of the students remained at level 1, 4.2% reached level 3, and 29.2% reached level 4.

Table 6 presents the statistical differences and the comparison between the pre- and post-intervention phases in which the tasks were administered.

Table 6 shows statistically significant differences ($t(23) = -13.736$; $p = 0.001$; $d = 2.804$ [huge effect size]) in students' GLK between the pre- and post-intervention phases. A significant variation is observed in the M values obtained in the pre- and post-intervention phases, increasing from 1.979 to 3.813, respectively. These findings indicate that, in the pre-intervention phase, the students' M was below level 2, whereas after the intervention it was close to level 4. This difference demonstrates that, according to the previously established criteria, students showed progress across the various dimensions of CT and in the organization and interpretation of data in a double "Stem-and-leaf plot".

Table 7. Descriptive statistics and pre- and post-intervention comparison of PT

		M	SD	t	p	d	Effect size
T1	Pre-intervention	10.96	7.91	-11.87	0.001	2.422	Huge
	Post-intervention	30.42	3.11				
T2	Pre-intervention	1.35	1.39	-4.52	0.001	0.922	Large
	Post-intervention	5.75	5.13				
T3	Pre-intervention	0.00	0.00	-24.46	0.001	4.992	Huge
	Post-intervention	11.58	2.32				

Note. T1: Task 1; T2: Task 2; T3: Task 3

Performance by task

Table 7 presents the variations in students' mean performance across each task, comparing the pre- and post-intervention phases.

Table 7 presents the mean performance values of students in each task, comparing the pre- and post-intervention phases, with statistically significant differences observed across all analyzed tasks: task 1 ($t[23] = -11.87$, $p = 0.001$; $d = 2.422$), task 2 ($t[23] = -4.52$, $p = 0.001$; $d = 0.922$), and task 3 ($t[23] = -24.46$, $p = 0.001$; $d = 4.992$). It is important to highlight that the effect size was huge in task 1 and task 3, and large in task 2, indicating a positive variation in students' learning following the use of the HP applets.

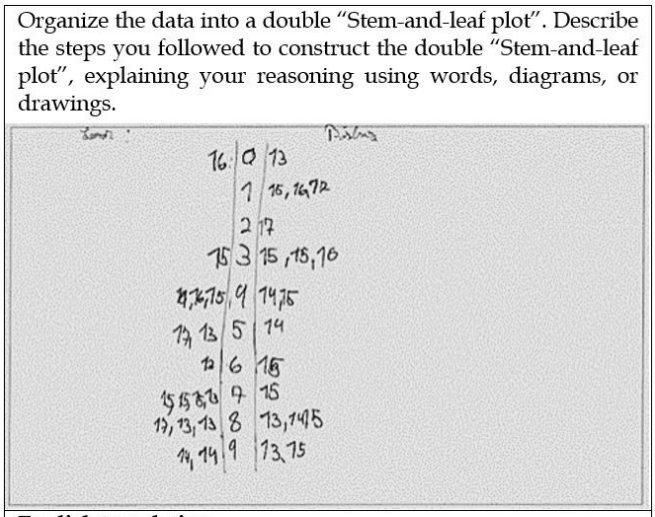
In task 1, a substantial increase in M values was observed (from 10.96 to 30.42), along with a reduction in SD, suggesting greater homogeneity within the class after the intervention. The results for this task indicate progress in students' ability to organize data and describe the steps involved in the construction process, demonstrating the development of the pattern recognition and algorithmic thinking dimensions of CT, particularly in describing procedures step by step.

Regarding task 2, although it presents lower M values, a statistically significant improvement was observed ($d = 0.922$). These results indicate that, throughout the intervention, there was progress in the abstraction dimension of CT, particularly in students' ability to identify and select essential information from problem statements for constructing "Stem-and-leaf plot".

In task 3, the most pronounced difference between the two phases is observed, with the M increasing from 0.00 in the pre-intervention phase to 11.58 in the post-intervention phase. This result, supported by the huge effect size in the study ($d = 4.992$), demonstrates an improvement in students' understanding of the elements of the "Stem-and-leaf plot" (title, source, and legend) and in their ability to verify the correctness of its construction, highlighting the development of the Debugging dimension of CT.

Qualitative Results

The qualitative results focus on the work of selected students, chosen to illustrate representative examples of different levels of performance identified within the class. The presentation is organized into three tasks (task 1, task 2, and task 3), and for each task, students' solutions collected during the pre- and post-intervention phases are presented, with the aim of highlighting the observed progression in the development of CT and in students' mathematical knowledge.



English translation

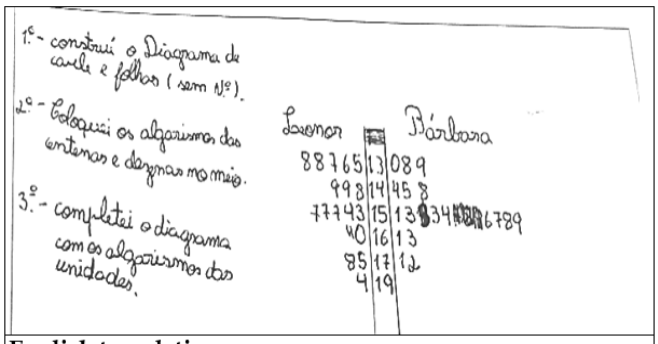
Left-hand heading: "Leonor:" | Right-hand heading: "Bárbara"

Leonor	Stem	Bárbara
16	0	13
	1	15, 16, 12
	2	17
15	3	15, 15, 16
14, 16, 15	4	14, 15
17, 13	5	14
12	6	15
15, 15, 8, 13	7	15
17, 13, 13	8	13, 14, 15
14, 14	9	13, 15

Figure 6. Student J's solution to task 1 in the pre-intervention phase (the authors' own work)

Pre-intervention (task 1)

In the pre-intervention phase, the solution to task 1 by student J (**Figure 6**) shows a lack of understanding regarding the organization of two data sets in a double "Stem-and-leaf plot". Furthermore, the student demonstrated a lack of knowledge of all the elements that should be included in such a "Stem-and-leaf plot", as only the title was provided. Additionally, the student did not present any description of the steps taken to construct the double "Stem-and-leaf plot", nor did they provide a complete solution to the task, in accordance



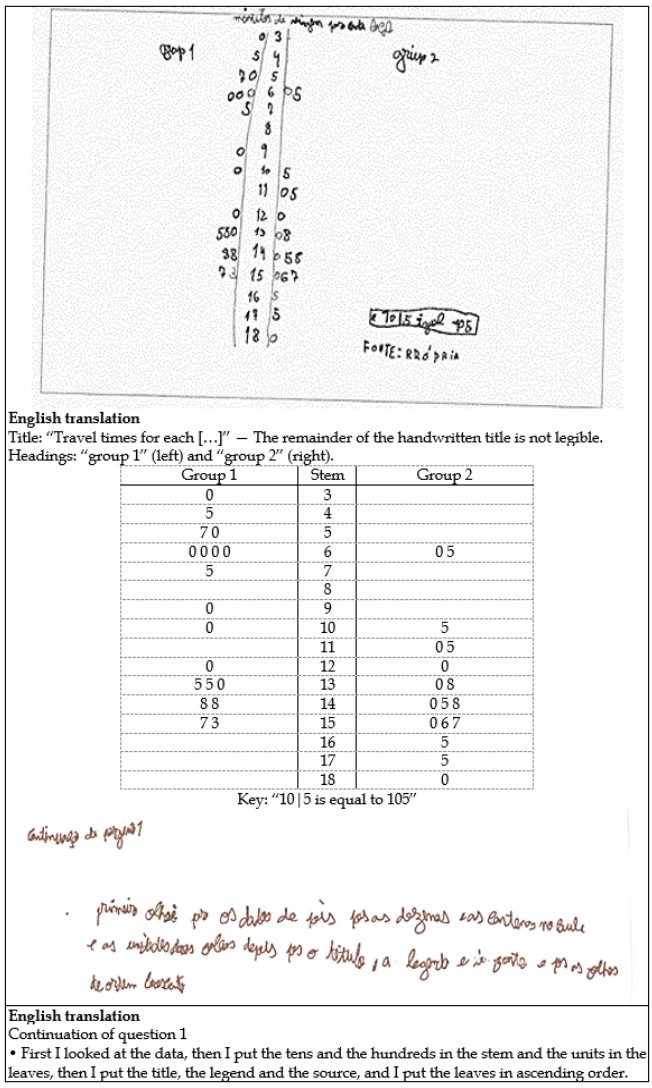
English translation
1st - I constructed the "Stem-and-leaf plot" (without no.).
2nd - I placed the hundreds and tens digits in the middle.
3rd - I completed the diagram with the units digits.

Leonor	Stem	Bárbara
8 8 7 6 5	13	0 8 9
9 9 8	14	4 5 8
7 7 7 4 3	15	1 3 [crossed out] 3 4 [crossed out] 6 7 8 9
4 0	16	1 3
8 5	17	1 2
4	19	

Figure 7. Student G's solution to task 1 in the pre-intervention phase (the authors' own work)

with the specific objectives defined for the dimensions of CT, namely pattern recognition, algorithmic thinking, and decomposition. Thus, according to the established criteria, the student was at level 2 in terms of mathematical knowledge and at level 1 in terms of the mathematical skills related to the dimensions of CT.

In the same task, the solution by student G (**Figure 7**) demonstrates an understanding of several concepts. This student shows an understanding that the leaves should be arranged in ascending order, starting from the value closest to the stem. It is also evident that the student recognizes the ascending order of the stems, from top to bottom, indicating an understanding that the tens and hundreds of each number form the stem. However, the omission of the value 18 in the stem stands out, revealing a lack of awareness of the need to include it, even when it is not represented in the data (pattern recognition). It is also observed that the student did not include the data source or an explanatory legend, providing only incomplete titles. Regarding the description of the construction process, student G is unable to clearly explain the steps involved, mentioning only the need to separate units from tens, placing the latter in the stem and the former in the leaves (algorithmic thinking). The student was able to decompose and carry out most of the procedures (decomposition), namely separating place values and ordering the leaves, but failed to correctly organize all rows and to identify the empty stem (18). This highlights weaknesses in the skills associated with CT. Thus, according to the established criteria, the student is at level 2 in terms of mathematical knowledge. Regarding the dimensions of CT, the student is at level 3 in pattern recognition and decomposition, and at level 2 in algorithmic thinking.



English translation
Title: "Travel times for each […]" — The remainder of the handwritten title is not legible.
Headings: "group 1" (left) and "group 2" (right).

Group 1	Stem	Group 2
0	3	
5	4	
7 0	5	
0 0 0 0	6	0 5
5	7	
	8	
0	9	
0	10	5
	11	0 5
0	12	0
5 5 0	13	0 8
8 8	14	0 5 8
7 3	15	0 6 7
	16	5
	17	5
	18	0

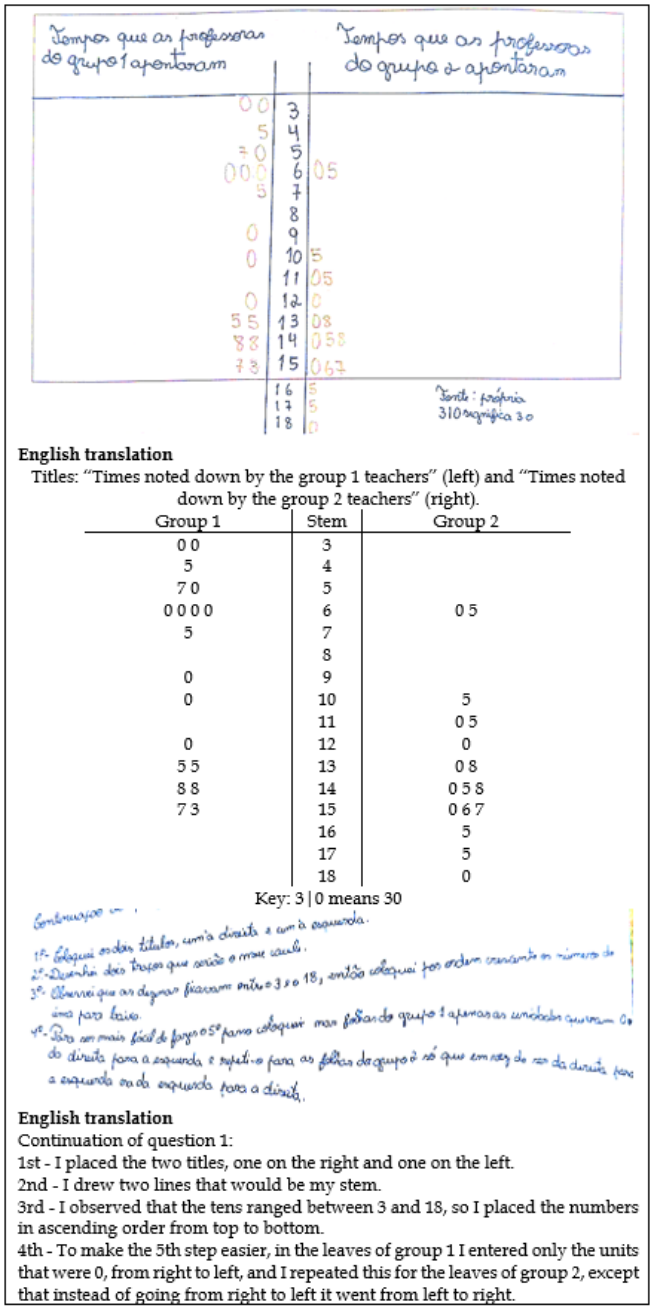
Key: "10 | 5 is equal to 105"

English translation
Continuation of question 1
• First I looked at the data, then I put the tens and the hundreds in the stem and the units in the leaves, then I put the title, the legend and the source, and I put the leaves in ascending order.

Figure 8. Student J's solution to task 1 in the post-intervention phase (the authors' own work)

Post-intervention (task 1)

In the post-intervention phase, the solutions to task 1 by student J and student G (**Figure 8** and **Figure 9**) demonstrate the ability to correctly construct a double "Stem-and-leaf plot", presenting only minor errors in the organization of the leaves. Both students were able to include all the essential elements required for interpreting the "Stem-and-leaf plot" (title, source, and legend). Another aspect to consider relates to the dimensions of CT. After the intervention, the students were able to recognize patterns in the construction process of the double "Stem-and-leaf plot" (pattern recognition), describe and sequence the steps involved in its construction (algorithmic thinking), and break down the construction into simpler tasks (decomposition). Thus, according to the established criteria, student J and student G reached level 4 in both mathematical knowledge and in the mathematical skills associated with the dimensions of CT, particularly pattern recognition, algorithmic thinking, and decomposition.



English translation

Titles: "Times noted down by the group 1 teachers" (left) and "Times noted down by the group 2 teachers" (right).

Group 1	Stem	Group 2
0 0	3	
5	4	
7 0	5	
0 0 0 0	6	0 5
5	7	
	8	
0	9	
0	10	5
	11	0 5
0	12	0
5 5	13	0 8
8 8	14	0 5 8
7 3	15	0 6 7
	16	5
	17	5
	18	0

Key: 3 | 0 means 30

Continuação da questão 1:
1º- Coloquei os dois títulos, um à direita e um à esquerda.
2º- Desenhei dois traços que seriam o meu caule.
3º- Observei que as dezenas ficaram entre 3 e 18, então coloquei por ordem crescente os números de uma para traz.
4º- Para ser mais fácil de fazer o 5º passo coloquei meu folhas do grupo 1 apenas as unidades começou do direito para a esquerda e repeti-o para as folhas do grupo 2 só que em vez de ser da direita para a esquerda era da esquerda para a direita.

English translation

Continuation of question 1:
1st - I placed the two titles, one on the right and one on the left.
2nd - I drew two lines that would be my stem.
3rd - I observed that the tens ranged between 3 and 18, so I placed the numbers in ascending order from top to bottom.
4th - To make the 5th step easier, in the leaves of group 1 I entered only the units that were 0, from right to left, and I repeated this for the leaves of group 2, except that instead of going from right to left it went from left to right.

Figure 9. Student G's solution to task 1 in the post-intervention phase (the authors' own work)

Identify the information in the problem statement that was essential for constructing the double "Stem-and-leaf plot".

As informações foram essenciais

English translation

The information was essential.

Figure 10. Student K's solution to task 2 in the pre-intervention phase (the authors' own work)

Pre-intervention (task 2)

In the pre-intervention phase, student K, in the solution to task 2 (**Figure 10**), provided a general response without specifying any of the essential information required for constructing the double "Stem-and-leaf plot" (abstraction dimension of CT). Thus, according to the established criteria, student K was at level 1 in terms of the mathematical skill related to the abstraction dimension of CT.

Os números e o caule-e folhas.

English translation

The numbers and the stem-and-leaf plot.

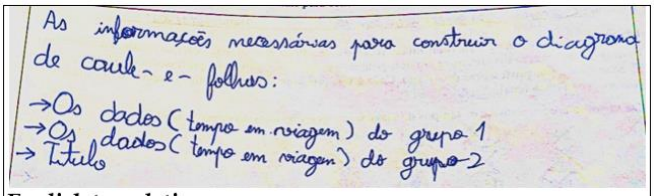
Figure 11. Student C's solution to task 2 in the pre-intervention phase (the authors' own work)

os dados, o enunciado e a fonte/própria

English translation

The data, the problem statement and the source.

Figure 12. Student K's solution to task 2 in the post-intervention phase (the authors' own work)



English translation

The information needed to construct the "Stem-and-leaf plot":
→ The data (travel time) of group 1
→ The data (travel time) of group 2
→ Title

Figure 13. Student C's solution to task 2 in the post-intervention phase (the authors' own work)

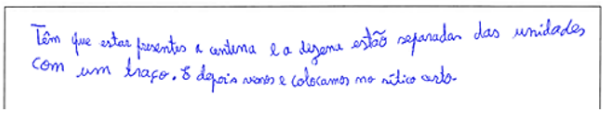
In the same phase, the solution by student C (**Figure 11**) demonstrates an understanding that the data constitute essential information for constructing the "Stem-and-leaf plot". However, the student does not specify the information needed to understand what the data represent (the heights of the guests at Bárbara's party and the heights of the guests at Leonor's party). Consequently, according to the criteria defined for the abstraction dimension of CT, student C was at level 2.

Post-intervention (task 2)

In the post-intervention phase, student K, in the solution to task 2 (**Figure 12**), was able to refer to the data and the problem statement that encompasses the information related to those data. Thus, according to the defined criteria, the student was at level 2 in terms of mathematical knowledge in the abstraction dimension of CT.

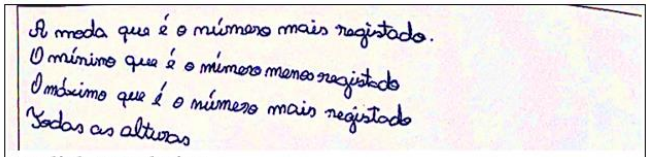
The solution by student C (**Figure 13**) presents, in detail, all the information considered essential for solving task 2. By identifying all the required information, the student was at level 4, according to the defined criteria related to the abstraction dimension of CT.

Check whether you constructed the double "Stem-and-leaf plot" correctly in task 1. Identify all the elements that must be included in a double "Stem-and-leaf plot". Explain your thought process using words, diagrams, or drawings.



English translation
The hundreds and the tens must be present, they are separated from the units by a line. And then we go and place them in the right place.

Figure 14. Student O's solution to task 3 in the pre-intervention phase (the authors' own work)



English translation
The mode, which is the most frequently recorded number.
The minimum, which is the least recorded number
The maximum, which is the most recorded number
All the heights

Figure 15. Student G's solution to task 3 in the pre-intervention phase (the authors' own work)

Pre-intervention (task 3)

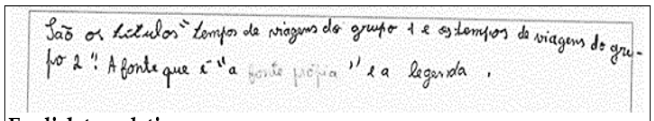
The solution to task 3 by student O, in the pre-intervention phase (**Figure 14**), shows that the student does not identify any of the three elements of the "Stem-and-leaf plot" (title, legend, and source), as the focus is placed solely on the structure of the "Stem-and-leaf plot". Furthermore, the student does not indicate whether the constructed "Stem-and-leaf plot" is correct. According to the defined criteria, student O was at level 1 both in terms of mathematical knowledge and in the debugging dimension of CT.

In the same task, student G (**Figure 15**) demonstrates difficulties in identifying the constituent elements of a double "Stem-and-leaf plot". The student indicates the mode, minimum, and maximum and, for this reason, does not verify the correctness of the constructed double "Stem-and-leaf plot", as required by the task. Thus, according to the established criteria, student G was at level 1.

Post-intervention (task 3)

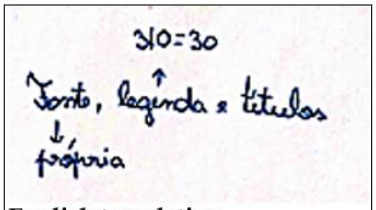
In the post-intervention phase, the solution by student O (**Figure 16**) shows that the student correctly and clearly identified the three elements of a "Stem-and-leaf plot". Thus, according to the established criteria, student O was at level 4.

The solution provided by student G (**Figure 17**) shows that the student not only identified all the elements of the "Stem-and-leaf plot" but also supported the response by referring to the "Stem-and-leaf plot" they constructed. This exemplification demonstrates that



English translation
They are the titles "travel times of group 1 and the travel times of group 2". The source, which is "the own source", and the legend.

Figure 16. Student O's solution to task 3 in the post-intervention phase (the authors' own work)



English translation
3 | 0 = 30
Own source, legend and titles

Figure 17. Student G's solution to task 3 in the post-intervention phase (the authors' own work)

the student mobilized the three elements to verify the correctness of their own "Stem-and-leaf plot". Therefore, according to the established criteria, student G was at level 4.

A comparative analysis of students' solutions in the pre- and post-intervention phases made it possible to identify the main difficulties encountered in each task and to analyze their evolution between the two moments. **Table 8** summarizes these difficulties, relating them to the corresponding specific objectives and presenting the absolute and relative frequencies of students at negative LK (level 1 and level 2) in the pre- and post-intervention phases. This synthesis allows the difficulties identified through the qualitative analysis of students' solutions to be articulated with their quantitative expression across the entire group of students, highlighting patterns of change between the two moments.

Table 8 reveals distinct patterns in the evolution of the identified difficulties. Following the intervention, no students' solutions remained at negative levels for the objectives associated with data representation, pattern recognition, decomposition, and identification of the elements of the plot. Difficulties persisted in the objectives involving the written and ordered explanation of the solution process (algorithmic thinking), the identification of essential information needed to solve the task (abstraction), and the autonomous verification of the correctness of the constructed plot (debugging). However, the frequency of students at negative levels decreased in all three cases. These findings therefore indicate that progress was more pronounced in objectives involving construction and identification procedures than in those requiring students to explicitly explain and autonomously evaluate their work.

Table 8. Difficulties identified and students at negative LK

Difficulty identified	Specific objective	Students at negative levels: % (n)	
		Pre-intervention	Post-intervention
Representation of data in a double "Stem-and-leaf plot", including the source, title, and legend	T1-O1	95.8 (23)	0.0 (0)
Recognition of the patterns involved in constructing the plot, namely separating tens and units and using a single stem (pattern recognition)	T1-O2	33.3% (8)	0.0 (0)
Written explanation of the solution process, describing and ordering the steps followed (algorithmic thinking)	T1-O3	91.7 (22)	37.5 (9)
Decomposition of the construction of the plot into simpler tasks (decomposition)	T1-O4	33.3 (8)	0.0 (0)
Identification of the essential information required to solve the task (abstraction)	T2-O1	83.3 (20)	70.8 (17)
Identification of the elements that make up the plot	T3-O1	100 (24)	0.0 (0)
Autonomous verification of the correctness of the constructed plot (debugging)	T3-O2	100 (24)	66.7 (16)

Note. T1: Task 1; T2: Task 2; T3: Task 3; O1: Specific objective 1; O2: Specific objective 2; O3: Specific objective 3; O4: Specific objective 4

DISCUSSION

The analysis of the tasks applied in the pre-intervention phase revealed that the mean GLK of the students was below level 2, indicating difficulties both in students' mathematical knowledge related to "Stem-and-leaf plot" and in the skills associated with the dimensions of CT. These gaps highlight the importance of integrating technology with CT in educational contexts to create new opportunities for learning and development (Nordby et al., 2022; Papert, 1980). Following the intervention using the HP applets, statistically significant improvement and a huge effect size were observed in the GLK. This improvement indicates the potential of digital artefacts in promoting mathematical knowledge related to statistical literacy and in fostering the development of CT, supporting the perspectives of Almeida et al. (2021), Bobsin et al. (2020), Rodrigues et al. (2025), and Schlögl et al. (2017), who argue that the integrated use of CT with curricular content enhances the appropriation of scientific knowledge and promotes the development of students' cognitive skills. Throughout the sessions, students were observed to experience a general difficulty in expressing their solution processes in writing, particularly in activities that required them to explain their thinking and those involving skills such as algorithmic thinking and decomposition, in which students were asked to describe, step by step, how they solved the task (Brackmann, 2017). Although some students were able to explain their reasoning verbally with the support of guiding questions posed by the pre-service teacher, few were able to express this reasoning in writing on the exploration sheets. In this context, the mediation provided by the pre-service teacher, particularly using guiding questions, enabled students to reflect on their solutions and, in this way, overcome these difficulties (Canavarro et al., 2012).

The initial results revealed significant difficulties across each dimension of CT, reflecting the inherent complexity of these cognitive processes. In task 1, the dimensions of decomposition and pattern recognition stood out, from the pre-intervention phase, as the most developed among students, with all students reaching level 4 after the intervention. This progress supports the idea that providing contexts in which problems can be segmented facilitates their understanding and resolution (Angeli & Georgiou, 2023; Chaabi et al., 2025; Espadeiro, 2022). Additionally, encouraging the identification of regularities and similarities across different tasks enables the transfer of previously acquired strategies to new situations, as evidenced by students' ability to identify empty stems (Hsu & Tsai, 2024; Lee et al., 2022; Palop et al., 2025). The development observed in the algorithmic thinking dimension of CT, demonstrated by student G's ability to describe the step-by-step construction of the "Stem-and-leaf plot", is consistent with Yun and Crippen (2025), Voon et al. (2022), and Zeng et al. (2023), who highlight that this competence develops when students are faced with challenges requiring the sequential organization of steps.

In the abstraction dimension (task 2), an initial difficulty was observed among students in identifying the essential information required for the task, with most students at negative levels. The solutions provided by student K and student C in the pre-intervention phase illustrate this difficulty, as they failed to identify the crucial information needed to solve the task. However, the statistically significant improvement observed in the post-intervention phase suggests that this competence can be promoted through tasks that direct students' attention to the most important elements of the task, in line with Candeias et al. (2025). The improvement observed was the least pronounced across the three tasks, suggesting that the development of this dimension may require more sustained work than that provided by the four intervention sessions. These results may be related to the fact that, during the intervention, the exploration sheets asked students to underline the most important information needed to solve the task, without

requiring them to provide a written justification for their selection, as illustrated in the following excerpt:

> **Pre-service teacher A:** Okay, so you are asked to arrange the numbers in ascending order. Student K, in the group with student E, what were the most important pieces of information that you underlined?
>
> **Student A of group 6:** We underlined that the values in the table were in centimeters.
>
> **Pre-service teacher A:** Centimeters (underlines it on the board).
>
> **Student E of group 6:** And that the measurements should be arranged in ascending order.
>
> **Pre-service teacher A:** Okay, so you underlined that they had to be organized in centimeters and in ascending order. Is that enough? When we look at these data, do we know what is being analyzed if we do not have any other information here? (referring to the task statement) (MN from session 1 of the intervention phase).

The analysis of the debugging dimension of CT (task 3) revealed the most notable improvement in the study. Prior to the intervention, all students demonstrated difficulty in identifying the elements of the "Stem-and-leaf plot" and in verifying the correctness of its structure. These findings corroborate the evidence presented by Gao and Hew (2022), who argue that debugging is generally the dimension in which students experience the greatest difficulties, as they are not familiar with identifying flaws in their own strategies. In the post-intervention phase, students reached level 4 in identifying the "Stem-and-leaf plot" elements (title, source, and legend), as illustrated by student O's solution. However, the autonomous verification of the "Stem-and-leaf plot" remained a challenge, with most of the class remaining at level 1. Only a few students, such as student G, were able to verify the construction of their "Stem-and-leaf plot" (level 4). These results highlight the cognitive demands of the debugging process, which requires students to identify errors, inaccuracies, or aspects to be improved in their strategies, with the aim of refining their chosen solution (Albuquerque, 2021; Macann & Hartnett, 2025).

The results obtained are consistent with the gaps identified in previous reviews. Ye et al. (2023) highlight the scarcity of studies articulating the development of CT with the learning of mathematical content, particularly in the domain of statistics, while Santaengracia et al. (2026) point to the lack of descriptions of teaching practices that promote this capability in the early years of schooling. The findings presented here show that such articulation is feasible in a 4th-grade classroom, although progress varied across dimensions. Pattern recognition, decomposition, and algorithmic thinking showed more evident progress, whereas abstraction and debugging proved more challenging to develop. These differences suggest that integrating CT with statistical content does not benefit all dimensions to the same extent.

Considering the positive development observed across all dimensions of CT, this study has relevant implications for mathematics education. The improvement in students' LK regarding double "Stem-and-leaf plot" suggests that teaching practices should integrate mathematical knowledge with processes involving design, reflection, abstraction, and expression in tasks (Oliveira, 2019). Thus, the conceptual framework of the pedagogical intervention presented in **Figure 1**, which brings together ETP, the HP, exploration sheets, CT processes, and the mathematical content addressed across the four sessions, appears to have contributed to the learning gains observed. The study also confirms that integrating CT into the curriculum, in line with national guidelines (ME, 2021), enables students to acquire the skills necessary for problem-solving (Ausiku & Matthee, 2021; Carvalho et al., 2024; Haşlaman et al., 2024; Moschella & Basso, 2020; Rodrigues et al., 2025; Yun & Crippen, 2025).

The importance of CT in preparing students for current challenges is noteworthy, as the operationalization of its dimensions in teaching practices contributes to more meaningful learning, fostering greater student engagement in the pursuit of new knowledge and autonomy in the construction of their own learning (Conforto et al., 2018; Rodrigues et al., 2025). It was observed that students improved across all five dimensions of CT highlighted in the literature and in the mathematics curriculum, namely abstraction, decomposition, algorithmic thinking, debugging, and pattern recognition (Francisco et al., 2025; ME, 2021). The skills developed by the students are aligned with 21st century demands, such as problem-solving, cognitive flexibility, and critical thinking (World Economic Forum, 2016).

CONCLUSIONS

Considering the results obtained, it can be concluded that the integration of the applets "Stem-and-leaf plot" and "Data analysis – Mode, mean, and median" in the classroom, based on ETP, significantly contributed to improving the learning of 4th-grade students in primary school who participated in this study.

The 4th-grade students in primary school who participated in this study demonstrated significant progress in their understanding of graphical representations, particularly the "Stem-and-leaf plot", as well as in the development of the dimensions of CT. This progress was evident in the students' solutions

presented on the exploration sheets completed during the pre- and post-intervention phases. The analysis and comparison of each student's solutions revealed that the majority were able to correctly construct a double "Stem-and-leaf plot" from two sets of discrete quantitative data and to develop the various dimensions of CT, showing positive progress in both GLK and PT. Regarding the dimensions of CT, decomposition and pattern recognition emerged as the most developed skills, reaching the highest level of performance after the intervention. Although the debugging dimension showed the largest effect size, it proved to be the most cognitively demanding process, remaining a challenge for most students.

This study suggests that ETP enabled a more structured integration of digital artefacts. This exploratory approach allowed students to construct their knowledge in an active and meaningful way. The phases of the ETP model assumed a relevant role in students' learning. The autonomy granted to students during task completion using the applets, together with the mediation of the pre-service teacher, contributed to the learning process. Moments of discussion and clarification of doubts supported knowledge construction. During these phases, groups self-assessed and refined their responses, demonstrating understanding and autonomy. The tasks completed by students before and after the sessions enabled the analysis of the development and progression of their learning, both in terms of mathematical knowledge and in the development of the various dimensions of CT. Although the class had no prior experience with structuring lessons according to the four-phase model, students showed a positive response and a strong ability to adapt to this new pedagogical approach. Therefore, this study contributes to the understanding of CT as a mathematical competence by presenting a didactic proposal that connects the development of this competence with mathematical knowledge in the domain of data and probability using the HP within the framework of ETP.

Implications and Suggestions

The results of this study have relevant implications for mathematics teaching in primary school, demonstrating how the integration of digital artefacts, specifically the applets from the HP, structured within ETP, can simultaneously promote the development of statistical literacy and the five dimensions of CT. Given the significant progress observed across all the tasks analyzed, the findings suggest the relevance of using these digital artefacts in primary school, in articulation with curricular content and teaching practices that emphasize collective discussion and the systematization of learning. The progress observed in the development of CT further reinforces the importance of providing, within Initial Teacher Training, training experiences that prepare pre-service teachers to promote its different dimensions through the design and implementation of pedagogically grounded tasks and teaching practices, as well as to critically analyze the outcomes of their implementation, thereby contributing to the enactment of current curricular guidelines in this domain. Since the MN made it possible to identify the difficulties experienced by the pre-service teacher, particularly in managing time across the different phases of the lesson, the findings also highlight the potential of this instrument to support pre-service teachers' reflection on their own practice.

The results should be interpreted considering the study's limitations. The sample was small and limited to a single 4th-grade primary school class, and no control group was included. The intervention period was also relatively short, comprising four sessions. These conditions limit the generalizability of the findings. Regarding the implementation of the action plan, the MN revealed difficulties in managing the time allocated to the discussion of the task. Accordingly, future interventions should ensure appropriate time management to safeguard the systematization of mathematical learning phase.

In addition, future research should adopt larger and more diverse samples, encompassing other grade levels, to assess whether the observed effects are sustained across different educational contexts.

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