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OBSERVATION OF MATHEMATICS CLASSES WITH THE USE OF ROBOTS: DESIGN OF AN INSTRUMENT FOR GUIDING TEACHER REFLECTION

Paulina Toncio
Universidad Católica del Maule, Chile
https://orcid.org/0009-0003-3213-1793

Maria Jose Seckel
Universidad Católica de la Santísima Concepción, Chile
https://orcid.org/0000-0001-7960-746X

Carolina Marchant
Universidad Católica del Maule, Chile
https://orcid.org/0000-0003-1832-4444

Viviane Hummes
University of Barcelona, Spain
https://orcid.org/0000-0003-2031-8238

Abstract: The advance of society and technological development have led governments to transform their public policies in various areas, with a particular focus on the education system. In this context, many countries have focused their efforts on raising educational quality standards, especially in the development of digital competencies. This has generated the need to modify school curricula, incorporating Computational Thinking (CT) in areas such as mathematics. Several researches highlight the importance of providing tools to teachers to design meaningful pedagogical strategies that integrate mathematical thinking with CP, implementing innovative teaching practices that favor the development of skills in students. In line with these demands, the present research aims to design an instrument for the observation of mathematics classes that incorporate the PC through the programming of robots, in order to guide teaching reflection. The study is situated within an interpretive paradigm, with a mixed approach, and validates the content from both a quantitative and qualitative perspective. In conclusion, the instrument designed has proven to be a useful tool to guide teacher reflection, as it is structured in six key dimensions and has been validated in terms of clarity, coherence and relevance. However, the need was identified to add additional items to improve the sufficiency of some dimensions. Finally, a second validation process is suggested to ensure its reliability and applicability in different educational contexts.

Keywords: Mathematical Thinking. Computational thinking. Teacher Reflection. Class Observation Instrument.

INTRODUCTION

The progress of society and the advance of technological development have forced governmental organizations to transform their public policies in various dimensions, mainly in the areas of social, industrial and economic development. In this context, education has adapted from a content-based model to a paradigm of skills development, which is essential for insertion into a highly globalized and digitalized world (OECD, 2004; UNESCO, 2007). This development requires education systems to offer new competencies and skills for the 21st century, allowing students to benefit from new emerging forms of socialization and actively contribute to economic development (Institute of Educational Technologies, 2010).

In response to this need, the Organization for Economic Co-operation and Development (OECD) has categorized skills into several areas: ways of thinking, ways of working, tools for working and ways of living. Among the priorities is digital literacy, understood as the competence that every citizen must develop to be considered literate in the 21st century (Vázquez, Bottamedi and Brizuela, 2019). Thus, different countries have directed their efforts to raise the quality standards of their national education systems, particularly in the development of digital competence. Information and communication technologies (ICTs) and Computational Thinking (CT) have gained prominence in society, making their way into industry, communication, education, work and recreation. However, challenges exist not only in the acquisition and adoption of ICTs, but also in the more complex task of using technological resources to effectively facilitate innovation and educational improvement (Thomas and Knezek, 2008). One of the initiatives that has gained momentum at the international level is the integration of PC into the school curriculum (Caballero-González, García-Valcárcel, & García-Holgado, 2019). In this sense, England was one of the first countries to include the teaching of CP and programming in the primary and secondary school curriculum in 2014, laying the foundations that would guide curricular reforms in Europe (Bocconi et al., 2016). In Latin America and the Caribbean, Costa Rica stands out for its coverage and continuity in computer science education since the 1980s, followed by Argentina with the Program.ar program since 2013 (Borchardt and Roggi, 2017). Chile has also made systematic efforts in the integration of technologies in school education through the Enlaces program, the national plan for digital languages (Government of Chile, 2020), the creation of a mathematical deepening elective called "Computational Thinking and programming" (Mineduc, 2021) and the recent proposal to update the curriculum from first basic to second medium, in which digital literacy acquires prominence in the subject of mathematics.

However, despite the aforementioned efforts, the question arises as to whether teachers are trained to face the challenge of integrating CP development in the subject of mathematics and from the early levels of the school system (Seckel et al., 2021a; Seckel et al., 2021b). International research indicates a gap between curricular changes and adequate teacher preparation, particularly in the integration of CP (Balanskat and Engelhardt, 2015). Most teachers lack prior knowledge on these topics and are neither technically nor emotionally prepared for CP education (Ohashi, 2017). In parallel, the literature review shows the interest that has arisen to investigate teacher training processes on CP, which have been developed mainly in Europe and are characterized by considering theoretical and practical-reflective components. Regarding the latter component, teachers are expected to design teaching proposals in which CP is integrated and to reflect on the practice implemented to improve the designs (Rivera et al., 2023). In this regard, the question remains, is the simple provision of opportunities for reflection sufficient to improve teaching practices? As an answer to this question, various research in the field of mathematics teacher education argues that, in addition to opportunities for reflection, teachers need specific tools that direct their attention to relevant aspects of teaching (Nilssen, 2010; Star and Strickland, 2008; Sun and Van Es, 2015; Turner, 2012; Seckel and Font, 2020).

Given the aforementioned problems, it is essential to have tools that guide the processes of observation and reflection in mathematics classes, especially when PC is integrated. Although several instruments have been developed for the observation and reflection of mathematics classes (Vásquez et al., 2020), there are currently few tools that promote teacher reflection on the integration of mathematical and computational thinking in these classes. For this reason, the present study aims to design an observation rubric that contributes to the development of professional skills, helping teachers to improve their reflective practices and, consequently, their teaching design.

The general purpose of the study is to design an instrument for the observation of mathematics classes incorporating CP through the use of robots such as BeeBot (or similar). The specific objectives are to define the dimensions and components necessary for the design of the instrument and to validate it in terms of clarity, coherence, relevance and sufficiency.

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THEORETICAL FRAMEWORK

DIDACTIC SUITABILITY CRITERIA

The Criteria of Didactic Suitability (CID) is a theoretical notion developed within the framework of the Ontosemiotic Approach to Mathematical Knowledge and Instruction (EOS), used to analyze and evaluate teaching-learning processes. According to Godino (2013), this notion is applicable both to the implementation of class sessions and to the planning and development of didactic units, courses or curricular proposals. The CID are structured in six fundamental dimensions: epistemic, cognitive, interactional, mediational, emotional and ecological, each with specific components and indicators that facilitate the design, implementation and effective evaluation of pedagogical practices.

The application of the CIDs allows for a comprehensive and systematic evaluation of educational practices, guiding towards a more effective and reflective didactics. As Godino, Bencomo, Font and Wilhelmi (2007) point out, these criteria are not directly observable, so it is necessary to define specific indicators to guide the design, observation and evaluation of training actions. Table 1 presents the CIDs and their respective components and indicators, showing only those corresponding to the epistemic and interactional CIDs for reasons of space.

DIDACTIC ORIENTATIONS FOR THE USE OF THE BLUE-BOT ROBOT (OR SIMILAR)

The instrument, focused on the teaching of mathematics with the use of pedagogical robots and their implication in learning, has been designed taking as a reference the twelve didactic orientations proposed by Seckel, Salinas, Font and Sala-Sebastiá (2023), which emerge from the literature review and are related to the Didactic Suitability Criteria. Table 2 **presents** the twelve didactic orientations in general.

METHODOLOGY

The validation process of the rubric was carried out through a mixed study, in the first phase a quantitative study was conducted and, in the second, a qualitative one. Specifically, in the first phase the content validity technique was applied by expert judgment (Hernandez-Nieto, 2011), while in the second phase the content analysis technique was applied (Cáceres, 2003). After obtaining the quantitative and qualitative results, the final design of the rubric was arrived at. This section will present a brief description of the initial design of the instrument and describe the methodological processes that guided the data analysis.

The design of the rubric contemplated six dimensions or categories based on the CID construct (epistemic, cognitive, interactional, interactional, mediational, affective and ecological), which were described in the previous section. The initial rubric had 12 items. Items 1 to 4 are related to the epistemic category, 5 to 7 to the cognitive, 8 and 9 to the interactional, 10 to the mediational, 11 to the affective and 12 to the ecological.

The validation process considered the participation of five expert judges, who were selected based on the following criteria: 1) researchers with a master's or doctoral degree, 2) demonstrable research experience in Mathematics Education and PC development using the Beebot robot (or similar) and 3) researchers with knowledge of the theory of didactic suitability. These judges evaluated the rubric considering four parameters: 1) clarity, 2) coherence, 3) relevance and 4) sufficiency. For such evaluation, the rubric proposed by Galicia, Balderrama and Edel (2017) was given, which considers a score from 1 to 4 (see Table 3).

Components	Indicators
Epistemic CID	
Errors	No practices are observed that are considered incorrect from a mathematical point of view.
Ambiguities	No ambiguities are observed that could lead to confusion among students: definitions and procedures clearly and correctly stated, adapted to the educational level to which they are addressed; adequacy of explanations, verifications, demonstrations to the educational level to which they are addressed, controlled use of metaphors, etc.
Richness of processes	The sequence of tasks contemplates the realization of relevant processes in mathematical activity (modeling, argumentation, problem solving, connections, etc.).
Representativeness	The partial meanings (definitions, properties, procedures, etc.) are a representative sample of the complexity of the mathematical notion to be taught contemplated in the curriculum. Partial meanings (definitions, properties, procedures, etc.) are a representative sample of the complexity of the mathematical notion to be taught. For one or more partial meanings, representative sample of problems. For one or more partial meanings, use of different modes of expression (verbal, graphic, symbolic...), treatments and conversions between them.
Interactional CID	
Teacher--teacher interaction	The teacher makes an adequate presentation of the topic (clear and well-organized presentation, does not speak too fast, emphasizes the key concepts of the topic, etc.). Students' conflicts of meaning are recognized and resolved (correct interpretation of students' silences, facial expressions, questions, appropriate question-answer game, etc.). We seek to reach consensus based on the best argument. A variety of rhetorical and argumentative devices are used to engage and capture the attention of students. It facilitates the inclusion of students in the dynamics of the class rather than exclusion.
Interaction between students	Dialogue and communication among students is encouraged. Inclusion in the group is favored and exclusion is avoided.
Autonomy	Moments are contemplated in which students assume responsibility for the study (exploration, formulation and validation).
Formative evaluation	Systematic observation of students' cognitive progress.

Table 1. *Characterization of the construct Didactic Suitability Criteria*

Source: adapted from Breda et al. (2018).

CID	Didactic orientation	Orientation description
Epistemic	1) Robotic problem idea.	For the design of mathematical tasks using the Bee-bot robot (or similar), it is essential to take into account the idea of a robotic problem. A robotic problem has a starting point (or 0 state) and an end point (final state).
	2) Types of tasks for robot introduction.	In order to introduce the use of the robot, three types of tasks must be considered 1. Unplugged tasks: Consist of tasks that develop TC without manipulation of the robot or digital platforms. For example: creating a large carpet for students to move from one point to another following instructions. 2. Specific tasks: these consist of manipulating the robot for programming and/or the complementary resources necessary for the execution of the task. Digital tasks: consist of the development of programming tasks through digital platforms, such as the Blue's Blocs app and Scratch, among others.
	3) Approaches to task design.	Two approaches to task design should be considered. The first type are robotic problems that integrate mathematical and computational concepts, and the second type are robotic problems that reinforce mathematical concepts.
	4) Promotion of mathematical skills.	It is recommended that task management promote mathematical skills. Regardless of the type of task (integration of mathematical and computational concepts and/or reinforcement of mathematical concepts), task management allows for the enhancement of mathematical skills (problem solving, representing, modeling, communicating and arguing, in accordance with the skills stated in the Chilean mathematics curriculum).

Cognitive	5) Degrees of difficulty of robotic problems.	The tasks should be presented considering progressive degrees of difficulty. We can recognize different degrees of difficulty in robotic problems. In the case of the Bee-Bot robot (or similar), the degree of difficulty is associated with the programming language required to answer the problem and/or the conditions that must be met according to the proposed programming scenario (e.g., a mat).
	6) Adaptation of robotic problems.	Evaluate the need to adapt the programming scenarios (mats) to respond to the particular needs of the student body. Consideration of this orientation allows all students to achieve the objective of the assignment.
	7) Promotion of working memory.	Reinforce working memory for its usefulness in mathematics. Working memory, which consists of maintaining and updating information in short-term memory, is a type of executive function (cognitive control), which is required when we need to concentrate to respond to a challenge (Diamond, 2013). Di Lieto et al. (2017) highlight the relevance of practicing working memory from early childhood education as it is an executive function that predicts mathematical skills.
Interactional	8) Promotion of collaborative work.	Encourage dialogue and communication among students. It is suggested that these programming tasks be assumed as challenges, where students have spaces to work collaboratively, discuss ideas and reach a consensus on viable solutions. In this line, promoting collaborative work in robots such as Bee-Bot robot programming has advantages such as increasing the chances of finding a solution by going through a process of co-construction in which learning is discussed, fed back and reformulated, and generates cohesion when reaching agreements, allows reaching higher levels of confidence and optimizes the use of time and resources.
	9. Free exploration and manipulation of the robot.	To provide spaces for free exploration and manipulation. One way to foster autonomy in students is to create a space of free manipulation of the Bee-Bot robot (or similar), where students are the protagonists of their learning, directing it and intuitively discovering the functions of each programming command. This also means providing students with opportunities to create questions or formulate hypotheses that are verified through experimentation.
Mediacional	10) Use of appropriate complementary resources for the development of the problems.	Use complementary resources of the robot. The use of the following complementary resources is suggested: 1. Command cards: they allow planning the robot programming, improving the debugging (error correction) and representation processes. It is also recommended to use larger cards so that the planning suggested by a student or group of students is visible to all members of the class. Grid mat: corresponds to the programming scenario, which can cover different themes depending on the learning objective to be achieved. Each grid of the mat should have a dimension of 15 × 15 cm, and this can be presented in numerous ways. On the other hand, the use of human scale mats is suggested to address the disconnected work level (without robots) or small scale when it is requested to represent the trajectories that the robot has performed when executing the programming.
Affective	11) Promotion of involvement in the task.	Promote involvement in the task. Although the use of the robot is highlighted as a manipulative resource that generates positive attitudes in mathematics lessons, it is important to recognize that this resource alone does not ensure a permanent positive attitude. In this sense, it is recommended that, during lessons, teachers consider some factors that could negatively impact students' attitudes towards task solving. These are: 1) Consider an adequate number of robots, considering the number of students in the course. The idea is that everyone plays an active role during the development of the problems. 2) Assign roles for the development of the task through collaborative work, where all students can participate in the activities and are valued as contributors to the achievement of a task.
Ecological	12) Interdisciplinary Connections.	Encourage connections between the contents of different subjects. The mat is a resource that allows interdisciplinary connections to be made through a variety of topics that can link mathematical content with that of other subjects (natural sciences, social sciences and physical education, among others).

Table 2. Didactic orientations and their relation to the IDCs

Source: own elaboration based on Seckel et al. (2023).

Parameter	Evaluation			
	1	2	3	4
Clarity: The item is easy to understand, it is syntactics and semantics are appropriate	The item is not clear	The item requires either quite a few modifications or a very large modification in the use of the according to their meaning or by the order in which they are arranged.	A very specific modification of some of the terms of the item is required.	The item is clear, has adequate semantics and syntax
Consistency: The item is logically related to the dimension or indicator you are measuring	The item has no logical relationship to the dimension	The item has a tangential relationship with the dimension	The item has a moderate relationship with the dimension it is measuring.	The item is completely related to the dimension it is measuring.
Relevance: The item is essential or important, it is i.e., it must be included	The item can be deleted without affecting the measurement of the dimension.	The item has some relevance, but another item may be including what this item measures.	The item is relatively important	The item is very relevant and should be included.
Sufficiency: The items that belong to a same dimension are sufficient to obtain the measurement of this	The items are not enough to measure the dimension	The items measure some aspect of the dimension, but do not correspond to the total dimension.	Some items should be increased in order to fully assess the dimension.	The items are not enough

Table 3. *Evaluation parameters*

As mentioned above, in the first phase of data analysis, in order to measure the degree of agreement of the expert judges regarding each of the items and the design of the rubric in general, the data were analyzed through the Content Validity Coefficient (CVC) technique (Hernández-Nieto, 2011). In this way, the results were interpreted as set out in Table 4.

Interpretation of validity and concordance	Value of CVC
Unacceptable	Less than 0.60
Deficient	Equal to or greater than 0.60 and less than or equal to 0.70
Acceptable	Greater than 0.71 and less than or equal to 0.80
Good	Greater than 0.80 and less than or equal to 0.90
Excellent	Greater than 0.90

Table 4. *Content validity coefficient interpretation scale.*

Source: Hernández-Nieto (2011).

Considering this interpretation scale, in the second qualitative phase, the relevance of maintaining those items with a CVC higher than 0.71 and less than or equal to 0.80 (acceptable validity and agreement) was analyzed based on the recommendations of the panel of experts. Also, at this stage, the rubric was reviewed and corrected, considering the recommendations provided by the judges in four areas (Fernández-Morales et al, 2015): i) appropriate use of words, ii) adequacy of the meaning of the wording to measure only one objective and iii) incorporation of an item to strengthen the sufficiency of a given dimension.

Once the analysis process was completed, the need to maintain, eliminate, adjust and/or add items to the rubric was determined, resulting in the final design.

RESULTS

QUANTITATIVE PHASE RESULTS

Table 5 shows the results obtained in the evaluation of the instrument by the five expert judges with respect to the parameters of coherence, clarity and relevance of each of the items.

As shown in the table above, all the items obtained a good or excellent rating, which determines the permanence of the 12 items in the proposed instrument. On the other hand, Table 6 shows the results obtained in the evaluation

Item	JUDGES					$\sum_{xij}$	M_x	CVC_i	P_{ei}	CVC_{tc}
	1	2	3	4	5					
1	12	12	7	11	11	53	4,41	0,88	0,00032	0,88
2	12	12	9	11	11	55	4,58	0,91	0,00032	0,91
3	11	12	12	11	11	57	4,75	0,95	0,00032	0,94
4	12	12	12	11	11	58	4,83	0,96	0,00032	0,96
5	12	12	12	11	11	58	4,83	0,96	0,00032	0,96
6	12	12	12	11	11	58	4,83	0,96	0,00032	0,96
7	12	12	6	11	11	52	4,33	0,86	0,00032	0,86
8	12	12	3	11	11	49	4,08	0,81	0,00032	0,81
9	12	12	12	11	11	58	4,83	0,96	0,00032	0,96
10	12	12	3	11	12	50	4,16	0,83	0,00032	0,83
11	12	12	9	11	11	55	4,58	0,91	0,00032	0,91
12	12	12	12	11	12	59	4,91	0,98	0,00032	0,98

Table 5. *Evaluation of the coherence, clarity and relevance of each item*

items	JUDGES					$\sum_{xij}$	M_x	CVC_i	P_{ei}	CVC_{tc}
	1	2	3	4	5					
1	4	4	2	4	2	16	3,2	0,8	0,00032	0,79
2	4	4	2	4	2	16	3,2	0,8	0,00032	0,79
3	4	4	2	4	4	18	3,6	0,9	0,00032	0,89
4	4	4	1	4	2	15	3	0,75	0,00032	0,74
5	4	4	3	4	4	19	3,8	0,95	0,00032	0,94
6	4	4	4	4	4	20	4	1	0,00032	0,99

Table 6. *Evaluation of the adequacy of the items in each category*

EPISTEMIC DIMENSION		
1.1 Robotic Problem Design		
It is analyzed whether the proposed tasks incorporate the idea of robotic problem, observing how these tasks challenge students to apply mathematical and programming concepts in the solution of practical problems using the robot. A robotic problem is a situation or challenge to be solved through the programming of a robot. A robotic problem has a starting point (state 0) and an end point (end state).		
Basic	**Medium**	**Advanced**
The tasks present a basic or superficial integration of robotic problems, with little or no complexity in their design. The proposed tasks are not robotic problems	The tasks include robotic problems that use mathematical and programming concepts appropriately, but could be more challenging or creative. The proposed tasks meet the definition of a robotic problem (it has a starting point and an end point) but are not challenging.	The tasks incorporate complex, well-structured robotic problems that require significant integration of mathematical concepts and programming skills. The proposed tasks meet the definition of a robotic problem (it has a starting point and an end point) and are challenging for the children.
1.2 Types of tasks for PC development		
It is observed whether teaching practices consider different types of tasks for the development of CP in the classroom and whether they are presented in a progressive manner. To introduce the use of the robot, you should consider the following types of tasks: **Unplugged** tasks: refers to problems that are solved without the manipulation of a robot or digital platforms. **Concrete tasks:** those problems that are solved by manipulating the robot for programming. **Digital** tasks**:** Refers to programming problems that are solved through digital platforms. A progressive implementation of the tasks is expected, i.e., first working with unplugged tasks, then moving on to concrete tasks and, later, to digital tasks.		
Basic	**Medium**	**Advanced**

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One or two types of robotic problems are used, omitting or minimizing the use of the others. Lack of integration affects students' understanding and ability to fully apply what they have learned. The problems used do not adequately cover the learning objectives. A robotic problem requiring robot manipulation is presented but no previous work with unplugged tasks is observed.	All three types of robotic problems are used, but with variations in their effectiveness. Some problems are not fully aligned with learning objectives or integration between problem types could be more cohesive. Practical and theoretical application is present, but needs more integration. A robotic problem requiring robot manipulation is presented and the implementation of an unplugged task prior to the manipulation of this resource is considered. However, the unplugged task is poorly related to the robot programming language.	All types of robotic problems are used in an effective and balanced manner. Students apply theoretical concepts in unplugged problems, perform hands-on programming with the robot, and reinforce their learning on digital platforms. Each type of problem is clearly integrated and aligned with the learning objectives. A robotic problem requiring robot manipulation is presented and the implementation of an unplugged task prior to the manipulation of this resource is considered. The unplugged task has a close relationship with the robot programming language.
1.3 Approaches to Robotic Problems		
It is observed whether robotic problems consider one of the two possible approaches for implementation in the mathematics classroom. Approach 1: problems that integrate mathematical and computational concepts. For example: a problem in which they are expected to recognize patterns (loops). Approach 2: problems that reinforce mathematical concepts.		
Basic	**Medium**	**Advanced**
They present robotic problems with superficial integration of concepts. Problems with little depth and limited use of robotics to reinforce mathematical learning. The approach to the robotic problem is not clear. A superficial introduction of both mathematical and computational concepts is observed.	Present robotic problems with average integration of mathematical and computational concepts, providing opportunities for improvement. Adequate problems to apply knowledge, although they do not maximize the depth or potential of robotics. The robotic problem approach is clear, but an inadequate introduction of mathematical and/or computational concepts is observed.	Present robotic problems with excellent integration of mathematical and computational concepts. Problems that deepen both skills and use robotics in innovative ways to reinforce mathematics. The robotic problem approach is clear and an adequate introduction of mathematical and/or computational concepts is observed.
1.4 Promotion of Mathematical Skills		
The extent to which the proposed robotic problems promote the development of Mathematical Skills is observed. It refers to the process of designing and managing robotic problems that involve the application of mathematical skills, such as: representing, communicating and arguing and/or modeling.		
Basic	**Medium**	**Advanced**
Robotic problems and/or their management, have minimal connection to mathematical skills. Limited application of mathematical skills in the proposed tasks is evident. The proposed robotic problems and/or their management do not promote the development of mathematical skills.	The robotic problems are adequately related to mathematical skills. A consistent application of mathematical skills is observed in the proposed tasks. The robotic problems and/or their management moderately promote the development of mathematical skills.	Robotic problems are highly integrated with math skills. A deep and creative understanding of math skills is demonstrated through the proposed tasks. Robotic problems and/or their management highly promote the development of mathematical skills.
1.5 Promotion of computer skills		
The extent to which the proposed robotic problems promote the development of Computational Skills is observed. It refers to the process of designing and managing robotic problems that involve the application of computational skills, such as 1) incremental and iterative, 2) testing and debugging, 3) reuse and remixing, and 4) abstracting and modulating.		
Basic	**Medium**	**Advanced**
Robotic problems and/or their management have a minimal connection with computational skills. There is evidence of limited application of computational skills in the proposed tasks. The proposed robotic problems and/or their management do not promote the development of computational skills.	Robotic problems are adequately related to computational skills. A consistent application of computational skills in the proposed tasks is observed. The robotic problems and/or their management, moderately promote the development of computational skills.	Robotic problems are highly integrated with computational skills. A deep and creative understanding of computational skills is demonstrated through the proposed tasks. Robotic problems and/or their management highly promote the development of computational skills.
2. COGNITIVE DIMENSION		
2.1 Difficulty levels of robotic problems		

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The extent to which levels of difficulty are considered progressively in robotic problems is observed. The difficulty levels of a robotic problem are understood as: **Low difficulty level:** Refers to problems that require programming forward-backward movements (programming of a one-dimensional space). **Higher difficulty level:** Refers to problems that incorporate the programming of rotation commands (programming in a two-dimensional space).		
Basic	**Medium**	**Advanced**
The proposed problems involve programming in a one-dimensional space without variations or adaptations that increase the difficulty.	The proposed problems show an attempt to integrate the rotation commands, although the complexity and the use of two-dimensional space are limited.	The proposed problems integrate multiple rotation commands and other advanced programming elements in a progressive manner, both in one-dimensional and two-dimensional space.
2.2 Adaptation of robotic problems		
The extent to which the robotic problems are adapted to the individual needs of the students is observed. Adaptation to robotic problems is understood as adjustments made to the programming scenarios, i.e., the process of modifying and adjusting the conditions and challenges of the problem to ensure that all students can achieve the goal of the class. One way to adapt is to present the problem in parts (problem decomposition). In the context of robotic problem solving, individual student needs are understood as difficulties associated with the overall understanding of the problem and its respective solution in small steps.		
Basic	**Medium**	**Advanced**
Programming scenarios are not responsive to individual student needs.	Programming scenarios show moderate or poor adaptation to individual student needs.	The programming scenarios show appropriate adaptation to the individual needs of the students.
2.3 Promotion of working memory		
The extent to which questions are used to promote working memory during robotic problem solving is observed. To promote working memory through questioning, the following stages should be considered: Anticipation: This refers to asking questions that guide the student to anticipate his or her plan. For example, How do you plan to program the robot? Program: Refers to programming the robot. I understand: This refers to asking questions that encourage the student to explain the programming process. For example, How did you program the robot? Debugging: Refers to asking questions that lead the student to reflect and identify changes to improve the programming code. For example, What changes would you make to your programming? This step should be addressed when no answer to the robotic problem is found.		
Basic	**Medium**	**Advanced**
Questions are rarely used, do not promote working memory, and do not have a significant impact on robotic problem solving.	Questions are occasionally used at key moments, but they lack consistency, activate working memory at a basic level, and have a moderate impact on robotic problem solving.	Questions are frequent and strategically positioned throughout the process. They promote working memory and are highly relevant to robotic problem solving.
2.4 Evaluation		
The extent to which teachers implement evaluation processes that account for the appropriation of the mathematical and computational learning intended by integrating the use of the robot in the classroom is observed.		
Basic	**Medium**	**Advanced**
Teachers use basic and general evaluation methods that do not clearly reflect the appropriation of the intended mathematical and computational learning. There is no explicit relation between the evaluation and the learning objectives.	Teachers use some evaluation processes that allow them to partially observe the appropriation of the intended mathematical and computational learning. These processes are limited in scope and/or frequency, or their alignment with the learning objectives is partial.	The faculty consistently implements varied and specific assessment processes that clearly reflect the appropriation of intended mathematical and computational learning. These processes are precisely aligned with the learning objectives of the class, and allow for detailed evidence of student progress.
3. INTERACTIONAL DIMENSION		
3.1 Promotion of collaborative work		
The extent to which classroom management promotes collaborative work among students, allowing them to discuss ideas and reach consensus on solutions, is observed.		
Basic	**Medium**	**Advanced**

Classroom management promotes participation by some students, but collaborative work is minimal or nonexistent.	Classroom management promotes collaborative work among students, but it is sporadic or limited. Discussion of ideas among some students is observed.	Classroom management promotes collaborative work among all students. Discussion of ideas and consensus to find the solution is observed.
3.2 Free exploration and manipulation of the robot		
It is observed to what extent spaces are promoted where students explore and manipulate the robot autonomously, allowing students to generate their own questions and hypotheses and test their results in a safe and stimulating environment.		
Basic	**Medium**	**Advanced**
Students do not explore the robot autonomously and there are no opportunities for students to generate questions or hypotheses about its operation.	Students are able to explore and manipulate the robot with some autonomy and some attempts are observed to promote the generation of questions and hypotheses about its operation.	Students explore the robot autonomously and are encouraged to generate questions and hypotheses about its operation.
3.5 Promotion of teacher-teacher interaction		
The extent to which the teacher and students interact during the development of robotic problem tasks is observed.		
Basic	**Medium**	**Advanced**
Interaction between teachers and students is limited or superficial during the development of robotic problem tasks. The teacher provides general explanations and opportunities for interaction are minimal, without promoting active dialogue or responding to student concerns.	The teacher promotes a moderate interaction with the students during the robotic problem solving, providing explanations and answers to specific questions. There are moments of interaction and support, but these may be sporadic or directed to a small group of students, limiting more active and collaborative participation.	The teacher encourages continuous and meaningful interaction with students during the development of robotic problems. Actively participates in feedback, raises questions, motivates collaboration and guides the resolution process by resolving children's doubts, making sure to engage all students in a constructive dialogue that promotes learning.
4. MEDIATIONAL DIMENSION		
4.1 Use of appropriate complementary resources for the development of the problems.		
The extent to which appropriate complementary resources are used to solve robotic problems is observed. The following are referred to as complementary resources: 1) Human scale mat to develop unplugged tasks (without robots) or small scale when it is requested to represent the trajectories that the robot has performed when executing the programming. 2) Grid mat corresponding to the programming scenario (each grid must have a dimension of 15 × 15 cm). 3) Command cards that allow the planning of the robot programming (these should be visible to the whole class).		
Basic	**Medium**	**Advanced**
The selection and use of complementary resources are not adequate for the development of the class.	The selection and use of complementary resources are adequate, but not sufficient for the development of the class.	The selection and use of complementary resources are appropriate for the development of the class.
5. EMOTIONAL DIMENSION		
5.1 Promotion of involvement in the task		
The extent to which teachers promote the involvement of all students in robotic problem solving is observed. Factors that promote student engagement are: Number of robots: refers to considering an adequate number of robots according to the number of students in the course. Role assignment: refers to the assignment of roles for the development of the steps to achieve the solution of a robotic problem.		
Basic	**Medium**	**Advanced**
There are not enough robots for all students to actively participate and/or role assignment is non-existent.	One of the following factors is observed: Number of suitable robots. Assignment of appropriate roles.	There are enough robots for all students to actively participate and roles are appropriately assigned to each student.
6. ECOLOGICAL DIMENSION		
6.1 Interdisciplinary Connections		
It is observed to what extent robotic problems favor interdisciplinary connections between contents of different subjects. Interdisciplinary connections are understood as the linking of mathematics with the other disciplines considered in the curriculum.		
Basic	**Medium**	**Advanced**
Robotic problems focus on mathematics and are not linked to other disciplines in the curriculum.	Robotic problems link mathematics to other disciplines in the curriculum in a limited way.	Robotic problems link to mathematics and other curriculum disciplines in a clear way.

Table 7. *Rubric for observing math classes that integrate the use of the BeeBot robot (or similar).*

carried out by the five expert judges regarding the sufficiency parameter of each of the dimensions considered in the design of the instrument (epistemic, cognitive, interactional, mediational, affective and ecological).

The data in the table highlight the need to increase the number of items in the epistemic, cognitive and interactional categories. Therefore, the qualitative analysis presented below is crucial to determine the characteristics of the items to be incorporated in the instrument.

QUALITATIVE PHASE RESULTS

As described above, in this phase the evaluators' observations (written records) were analyzed considering: 1) appropriate use of words, 2) adequacy of the sense of the wording to measure only one objective, and 3) incorporation of an item to strengthen the sufficiency of a given dimension.

Regarding the appropriate use of words, the expert judges provided suggestions for minor changes and improvements in the wording of items 1, 3, 5, 7 and 10.

Regarding the adequacy of the meaning of the wording to measure only one objective, it is observed that the expert judges did not make any observations, so it was not necessary to restructure the construction of the proposed items.

Finally, in accordance with the results presented in Table 6, the expert judges suggested incorporating items related to the epistemic, cognitive and interactional dimensions. Regarding the epistemic dimension, it is suggested to include an item related to computational skills. Regarding the cognitive dimension, it is suggested to include an item related to the evaluation component. Finally, regarding the interactional dimension, it is suggested to include an item related to the teacher-discussant component.

Based on the analysis carried out, the final proposal of the rubric is presented in Table 7.

CONCLUSIONS

The general purpose of this study was to design a rubric for the observation of mathematics classes that integrate CP through the use of the BeeBot robot (or similar). In the first phase of the study, the theory of didactic suitability was adopted as the basis for the design of the instrument, which allowed structuring it in six fundamental dimensions: epistemic, cognitive, interactional, mediational, affective and ecological. In addition, the didactic orientations proposed by Seckel et al. (2023) were considered, incorporating the following key components: 1) epistemic: richness of processes and representativeness; 2) cognitive: curricular adaptation and high cognitive demand; 3) interactional: interaction among students and autonomy; 4) mediational: material resources; 5) affective: attitudes; and 6) ecological: intra- and interdisciplinary connections.

In the second phase of the study, the 12 proposed items were validated in terms of clarity, coherence and relevance, obtaining satisfactory results in these areas. However, in terms of item sufficiency, only the mediational, affective and ecological dimensions were fully validated. It was necessary to add additional items to achieve sufficiency in the epistemic, cognitive and interactional dimensions, thus completing the final design of the instrument with 15 items.

The validation process conducted by expert judges proved to be essential to ensure the scientific rigor of the instrument, as it allowed for a detailed and informed review. The feedback provided by the experts not only helped to improve the rubric, but also facilitated more informed decision-making by the researchers.

Finally, it is recommended that the instrument undergo a second validation process, following the approach proposed by Vásquez et al. (2020), which includes a calibration based on expert judgment and a pilot application to ensure its reliability and applicability in different educational contexts.

Although the work presented here is a first stage of validation, it constitutes a valuable scientific and pedagogical contribution, since it provides an instrument that allows the assessment of mathematics teaching and learning practices with the use of a robot (Beebot or similar).

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REFERENCES

Balanskat, A. y Engelhardt, K. (2015). Computing our future. Computer programming and coding. Priorities, school curricula and iniciatives across Europe. Brussels, Belgium: European Schoolnet. http://www.eun.org/documents/411753/817341/Computing+our+future_final_2015.pdf/d3780a64-1081-4488-8549-6033200e3c03

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A. y Engelhardt, K. (2016). Developing Computational Thinking in Compulsory Education: Implications for policy and practice. JRC Science for Policy Report. *European Commission*. https://doi.org/10.2791/792158

Borchardt, M. Roggi, I. (2017) *Ciencias de la Computación en los sistemas educativos de América Latina*. Cuaderno SITEAL/TIC Sistema de Información de Sistemas Educativos de Latinoamérica. UNESCO-OEI. Enero 2017. Buenos Aires, Argentina. https://unesdoc.unesco.org/ark:/48223/pf0000372138?posInSet=14&queryId=50ce768-e66c-4abb-aefe-be91c64352cb

Breda, A., Font, V., Lima, V. M. R., & Pereira, M. V. (2018). Componentes e indicadores de los criterios de idoneidad didáctica desde la perspectiva del enfoque ontosemiótico. *Transformación, 14*(2), 162-176.

Caballero-González, Y., García-Valcárcel, A. y García-Holgado, A. (2019). Learning computational thinking and social skills development in Young children through problema solving with educational robotics. *Association for Computing Machinery.* https://doi.org/10.1145/3362789.3362874

Cáceres, P. (2003). Análisis cualitativo de contenido: una alternativa metodológica alcanzable. *Psicoperspectivas, 2*, 53-82.

Hernández-Nieto, R. (2011). Instrumentos de recolección de datos en ciencias sociales y ciencias biomédicas. Venezuela: Universidad de los Andes.

Galicia, L., Balderrama, J. y Edel, R. (2017). Validez de contenido por juicio de expertos: propuesta de una herramienta virtual. Apertura, 9(2), 42-53.

Godino, J. D. (2013). Indicadores de la idoneidad didáctica de procesos de enseñanza y aprendizaje de las matemáticas. *Cuadernos de investigación y formación en educación matemática*, 111-132.

Godino, J. D., Bencomo, D., Font, V. y Wilhelmi, M. R. (2006) Análisis y valoración de la idoneidad didáctica de procesos de estudio de las matemáticas. Paradigma, XXVII (2), 221-252.

MINEDUC. (2021). Pensamiento computacional y programación. Ministerio de Educación. https://www.curriculumnacional.cl/614/articles-140146_programa.pdf

MINEDUC. (2024). Actualización curricular: bases curriculares 1° básico a 2° medio. Ministerio de Educación. https://www.curriculumnacional.cl/614/articles-351761_recurso_02.pdf

Nilsen, V. (2010). Encouraging the Habit of Seeing in Student Teaching. *Teaching and Teacher Education,* 26(3), 591-598.

OCDE (2004). Innovation in the Knowledge Economy. Implications for education and learning. París, Francia. 98p.

Ohashi, Y. (2017). Preparedness of Japan's Elementary School Teachers for the Introduction of Computer Programming Education. En V. Dagiene y A. Hellas (Eds.), Informatics in Schools: Focus on Learning Programming. ISSEP 2017. *Lecture Notes in Computer Science (Vol 10696, pp. 129-140). Helsinki, Finland: Springer International Publishing*. https://doi.org/10.1007/978-3-319-71483-7

Seckel, M. J. & Font, V. (2020). Competencia reflexiva en formadores del profesorado de matemática. magis, Revista Internacional de Investigación en Educación, 12 (25), 127-144. https://doi.org/10.11144/Javeriana.m12-25.crfp

Seckel, M.J.; Breda, A.; Font, V.; Vásquez, C. (2021a). Primary School Teachers' Conceptions about the Use of Robotics in Mathematics. Mathematics 2021, 9, 3186. https://doi.org/10.3390/math9243186

Seckel, M. J, Salinas, C., Font, V. y Sala-Sebastiá, G. (2023). Guildelines to develop computational thinking using the Bee-bot robot from the literature. Education and Information Technologies, 28, 16127–16151. https://doi.org/10.1007/s10639-023-11843-0

Seckel, M.J., Vásquez, C., Samuel, M. & Breda, A. (2021b). Errors of programming and ownership of the robot concept made by trainee kindergarten teachers during an induction training. Education and Information Technologies, 27, 2955–2975. https://doi.org/10.1007/s10639-021-10708-8

Star, J. R. y Strickland, S. K. (2008). Learning to Observe: Using Video to Improve Preservice Mathematics Teachers' Ability to Notice. *Journal of Mathematics Teacher Education,* 11(2), 107-125. https://doi.org/10.1007/s10857-007-9063-7

Sun, J. y Es, E. A. Van (2015). An Exploratory Study of the Influence that Analyzing Teaching has on Preservice Teachers' Classroom Practice. *Journal of Mathematics Teacher Education,* 66(3), 201-214. https://doi.org/10.1177/0022487115574103

Thomas, L. G. y Knezek, D. (2008). Information, Communications, and Educational Technology Standards for Students, Teachers, and School Leaders. *At International Handbook of Information Technology in Primary and Secondary Education*, pp 333-348, Springer, Boston.

Turner, F. (2012). Using the Knowledge Quartet to Develop Mathematics Content Knowledge: The Role of Reflection on Professional Development. *Research in Mathematics Education,* 14(3), 253-271. https://doi.org/10.1080/14794802.2012.734972

UNESCO (2007). Educación de calidad para todos. Un asunto de derechos Humanos. Documento de discusión sobre políticas educativas en el marco de la II Reunión Intergubernamental del Proyecto Regional de Educación para América Latina y el Caribe (EPT/PRELAC) 29 y 30 de marzo de 2007; Buenos Aires, Argentina. Santiago: OREALC- UNESCO.

Vázquez, A., Bottamedi, J. y Brizuela, M.L. (2019). Pensamiento computacional en el aula: el desafío de los sistemas educativos de Latinoamérica. *RIITE. Revista Interuniversitaria de Investigación en Tecnología Educativa*, 7, 26-37. Doi: 10.6018/riite.397901.

Vásquez Ortiz, C. A., Alsina Pastells, Á., Pincheira Hauck, N. G., Gea Serrano, M. M. y Chandia Muñoz, E. (2020). Construcción y Validación de un Instrumento de Observación de Clases de Probabilidad. *Enseñanza de las Ciencias, 38(2), 25-43.44 https://doi.org/10.5565/rev/ensciencias.2820*