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Reflections of future kindergarten teachers on the design of a mathematical instruction process didactic sequences with the use of robots

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Abstract

The purpose of this study is to analyze the reflections of future kindergarten teachers when designing didactic sequences with the use of the bee-bot robot. A qualitative methodological design was followed to achieve this objective, collecting the data through a written record prepared by the participants from collaborative work. A total of 25 future teachers participated, forming six working groups. The data were analyzed with the content analysis technique, considering the criteria of didactic suitability–epistemic, cognitive, interactional, mediational, affective, and ecological–and their respective components. The results suggest that at the moment prior to the design of the didactic sequences, the reflections of the groups of future teachers are related only to some criteria, while, in the design of the proposed teaching and learning process, the units of analysis were related to all six criteria. With the results obtained, it is concluded that a future implementation and observation of the design of didactic sequences by the participants would allow the participants to consider more components of the criteria when reflecting. In addition, it is concluded that training that contemplates the criteria of didactic suitability, would also allow future teachers to deepen their reflections, guiding them with these tools.

Keywords: mathematics education, computational thinking, future kindergarten teachers, didactic suitability criteria

INTRODUCTION

The current technological demand has driven the discussion about the use of technology in the field of education. In this line, one of the currents of the so-called digital literacy that has been a focus of interest among educators and researchers in recent years is computational thinking (CT) (Caballero-González & Muñoz-Repiso, 2021).

One of the arguments to introduce the development of CT at the school level is the need to train citizens to be creators of technology and not only consumers (Zapata-Ros, 2019). Wing (2006) argues that CT will allow today's students to control the tech technology tomorrow and solve real-world problems based on the fundamental concepts of computer science. Likewise, several authors propose that CT develops progressively, therefore, it is crucial to consider its development from an early age (Wing, 2010; Zapata-Ros, 2019).

This explains the trend observed in different countries (Argentina, Spain, the United States, and England, among others) when introducing CT into the school curriculum from early childhood education (Grover & Pea, 2013; Jara & Hepp, 2016), adopting different strategies for this. Some countries have chosen to introduce a CT subject while, in other cases, they have integrated the development of CT into the mathematics subject. The latter, given the historical relationship that has been assigned to these two types of thought (Papert, 1980).

In the case of Chile, there is incipient incorporation of CT into the school curriculum. The clearest signal in this

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Contribution to the literature

- The results of this study point to the importance of future kindergarten teachers, in addition to designing, implementing, and evaluating didactic sequences for the teaching and learning of mathematics.
- One contribution of the study carried out is that future kindergarten teachers, when designing didactic sequences with the help of robots, do not present a deep level of didactic reflection.
- One of the practical contributions of the study is to point out the importance of designing and implementing cycles or training programs for initial teacher trainees, with the use of pedagogical robots, which contemplate the six dimensions of didactic suitability (DSC).

regard corresponds to the incorporation of a CT subject in secondary education as an elective of mathematics, in which it is indicated:

> "Every subject of mathematics in the curriculum aims for students to develop mathematical thinking (MT), conceived with sufficient breadth to contain the CT that has been entrusted, precisely, to the teachers of the subjects of mathematics" (Mineduc, 2021, p. 24).

This approach allows us to interpret that the integration between CT and MT will be the curricular definition of the Ministry of Education of Chile at other educational levels. Considering that the training path proposed by Chile's national digital language plan contemplates the development of CP from 0 to 18 years old, it is essential to advance the development of teacher training programs of all educational levels in the field of CT. In particular, there is a need to introduce teacher training programs that seek to promote CT from early childhood (Acevedo-Borrega et al., 2022; Ribeiro et al., 2011; Seckel et al., 2021). Therefore, it is necessary to guide the kindergarten teachers to develop the MT through the CT and reflect on it, either from the resolution of programming tasks (Seckel et al., 2022) or, from the design of didactic sequences using robots adapted to the early school ages as a way of educational innovation (Benton et al., 2017; Leidl et al., 2017; Sáez & Cózar, 2017; Sullivan & Bers, 2015; Sullivan et al., 2017a, 2017b).

Kong et al. (2020) identified some important elements for successful CT teacher professional development. Within them, we highlight the importance they give to collective reflection on the teaching and learning processes of CT. When reviewing the literature, we recognize that various authors agree on considering this element in professional training programs (Estebanell et al., 2018; Sentance & Humphreys, 2018). However, no research has been developed that characterized the reflections that emerge when teachers or future teachers design teaching and learning sequences and learn to develop CT at the school level. In this sense, Breda and do Rosário Lima (2016) raise the importance of analyzing in-depth the reflections of teachers when they participate in a training program since this information is helpful to generate feedback elements that allow improving said programs. Considering this, a first question arises: how to analyze the reflections of teachers or future kindergarten teachers that emerge when designing a didactic sequence for CT development in mathematics class? To answer this first question, we propose to develop an analysis from the perspective of the didactics of mathematics, specifically using the theoretical construct of didactic suitability (Breda et al., 2018; Font et al., 2010). From this theoretical position, a second question arises: in what dimensions (epistemic, cognitive, interactional, mediational affective, and/or ecological) is the reflection of future preschool teachers focused when designing a teaching and learning process that articulates the MT and CT? To answer this question, two research objectives were proposed. The first objective is to analyze the reflections of future kindergarten teachers before designing didactic sequences to teach mathematics with the use of the bee-bot robot and the second objective is to analyze the reflections of future kindergarten teachers at the time of designing didactic sequences using the bee-bot robot. It is important to note that in the training process we worked with the bee-bot robot because it is one of the resources introduced in the public-school system of Chile to develop the CT in the first years of schooling.

THEORETICAL FRAMEWORK

This section presents theoretical foundations that guide teacher training so that they can develop the CT at the school level, highlighting, on the one hand, the component of reflection on practice as a common element in different training proposals and, on the other hand, presenting the construct of didactic suitability criteria (DSC) as a tool that allows analyzing the reflections of teachers in their class design processes.

Teacher Training for the Teaching of Computational Thinking

The use of technological resources in the mathematics class with the purpose of developing the CT in an integrated way is conceived as a didactic innovation, that is, it corresponds to a process of change experienced by teaching practices that, according to Aroza et al. (2016), must be accompanied by reflective processes. In this sense, several authors have given guidelines to train teachers in the development of the CT, and the idea of

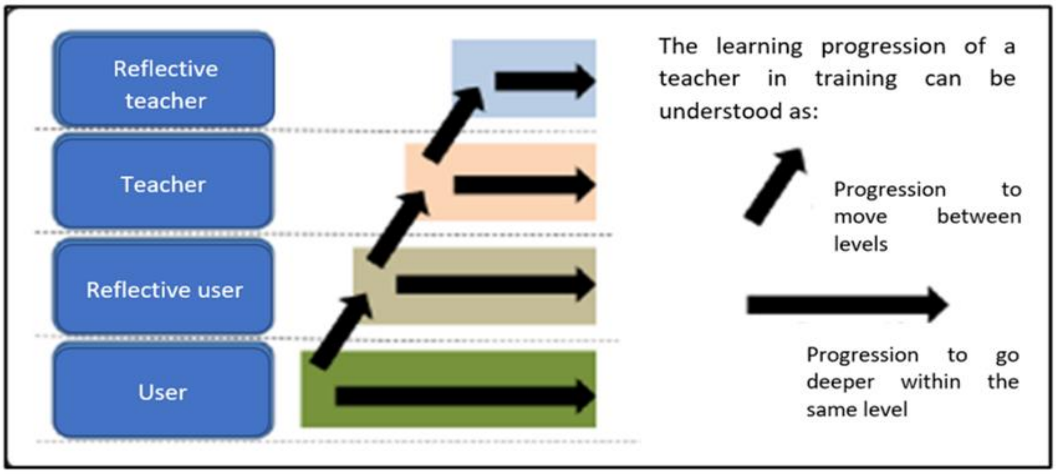

Figure 1. Levels of progression in CT learning in future teachers (Estebanell et al., 2018, p. 29)

reflective practices is recognized as a common element in their training proposals (Estebanell et al., 2018; Kong et al., 2020; Sentance & Humphreys, 2018).

Given the characteristics of the study, we will highlight the training proposal of Estebanell et al. (2018). These authors present a model that contemplates four levels for the development of CT (**Figure 1**).

At the user level, faculty are expected to raise questions about how to use a given computational language to address problems with a robot, video game, application, etc. At the reflective user level, it is intended that teachers reflect on what they have done when developing a computational problem.

At the teacher level, teachers are expected to face the challenge of deciding what to teach, what they expect their students to learn from CT, and what resources and strategies will be implemented, and at the last level, called reflective teacher, teachers are intended to reflect on the teaching and learning process related to CT.

It should be noted that the model proposes the progression of the training trajectory considering the transition of levels, as well as the deepening of training at each level.

Although this model explicitly considers reflection at levels 2 (reflective user) and level 4 (reflective teacher), several studies suggest that, when teachers are ready to design the instruction process, reflective processes are activated (Perrenoud, 2004; Seckel & Font, 2020), therefore, this study it is assumed that at level 3 (teacher) of this training model, reflections that are of interest in this study also emerge, understanding that the future teachers who participated in this research took a training module on the development of the CT based on the model presented.

Criteria of Didactic Suitability in/for the Design of Instructional Processes

In the design of tasks to develop CT at tat early age enough the programming of robots, it is necessary for teachers to recognize two basic aspects (Arlegui & Pina, 2016; Gusmão & Font, 2020). The first aspect is related to the idea of a task as a robotic problem, whose resolution implies that the robot goes from an initial state to a final one, through the planning of a sequence of actions (intermediate states that are programmed). The second aspect is related to criteria that should guide the approach of a problem or a sequence of problems, these are:

1. be of progressive complexity,
2. refer to known and unknown aspects, and
3. place the problem in an environment (scenario or the context).

However, to design a teaching and learning process that develops the CT at an early age with the use of the bee-bot, in which the learning objectives, the design of the proposed task, and a description of the teaching and learning process are considered, it is necessary to use a tool that guides about the aspects that must be considered so that the instruction is ideal. In this research, we assume that this tool is the DSC of the onto semiotic approach (OSA) to mathematical knowledge and instruction (Godino et al., 2007).

In the OSA, the didactic suitability of a teaching-learning process is understood as the degree to which it (or a part of it) meets certain characteristics that allow it to be qualified as suitable (optimal or adequate) to achieve adaptation between the personal meanings, achieved by the students (learning), and the institutional meanings intend-ed or implemented (teaching), considering the available circumstances and resources (environment). DSCs are considered principles that can serve first to guide the teaching and learning processes of mathematics and, second, to assess their implementation (Breda et al., 2018).

In the OSA the following DSC (Font et al., 2010) are considered: Epistemic suitability, to assess whether the mathematics being taught is "good mathematics". Cognitive suitability, to assess, before starting the

Table 1. Didactic suitability: Criteria and components

DSC	Components
Epistemic	Errors, ambiguities, process richness, & representativeness
Cognitive	Previous knowledge, curricular adaptation to individual differences, learning, & high cognitive demand
Interactional	Teacher-student interaction, interaction between students, autonomy, & formative evaluation
Mediational	Material resources, number of students, classroom schedule & conditions, & time
Affective	Interests & needs, attitudes, & emotions
Ecological	Adaptation to curriculum, intra & interdisciplinary connections, socio-labor utility, & didactic innovation

process of instruction, if what you want to teach is at a reasonable distance from what the students know, and after the process, if the learning acquired is close to what was intended to be taught. Interactional suitability, to assess whether the interactions solve doubts and difficulties of the students. Mediational suitability, to assess the adequacy of the material and temporal resources used in the instruction process. Affective suitability, to assess the involvement (interests and motivations) of the students during the instructional process. Ecological suitability, to assess the adequacy of the instruction process to the educational project of the center, the curricular guidelines, and the conditions of the social and professional environment.

For these criteria to be operational in the exercise of analysis and assessment of the construction processes, it is necessary to break them down into components and indicators. **Table 1** details the criteria and components of didactic suitability. The full table with the indicators can be found in Breda and do Rosário Lima (2016).

As explained in Breda et al. (2018), DSCs are a tool that:

a. allows the teacher to reflect on their practice and guide their improvement in the context where it is carried out;
b. it is multidimensional, it is decomposed into partial suitabilities and, in turn, each of them into components and indicators (Godino, 2013);
c. a teaching and learning process is considered appropriate when a balance is struck between the different partial criteria of suitability, and not when only some of them are met; and
d. partial suitability criteria (considered as a priori consensus) may conflict with the context in which the teacher works, which entails, first, treating the DSC jointly (and not as independent criteria) and, second, to question or relativize the validity of a certain criterion in a specific context, which leads to giving different relative weights to each criterion depending on the context.

In the review of the literature carried out by Breda et al. (2015), it is evident that the notion of didactic suitability has had a relevant impact on the training of teachers in different countries, experiences that have grown steadily over time (Mallart Solaz et al., 2016; Pochulu et al., 2016; Seckel & Font, 2015).

On the one hand, different investigations on the training of mathematics teachers are observed, in which the DSC is used to analyze the implicit use of these criteria in the reflections on teaching and learning practices of mathematics (own or others) (Breda, 2020; Breda et al., 2021; Hummes et al., 2020; Morales-López & Font, 2019; Moreira et al., 2018; Seckel et al., 2019) and, on the other hand, researches are observed on training programs in which the DSC are used as content to explain to organize the teacher's reflection on their own practice, in undergraduate (Seckel & Font, 2020) and postgraduate courses (Esqué de los Ojos & Breda, 2021; Font et al., 2017; Giacomone et al., 2018; Godino et al., 2018; Hernández-García & Breda, 2022).

METHODS

This research was developed through a qualitative methodology (Sandín-Esteban, 2000). The reflections of apprentice preschool teachers were studied when designing didactic sequences for teaching and learning mathematics using the bee-bot robot.

The research method corresponds to a case study (Stake, 1998), in which it is interesting to analyze the criteria considered by future kindergarten teachers during level 3 of a training module introduced in the subject of mathematics didactics (teacher level according to Estebanell et al., 2018).

Context and Participants

The study involved 25 future teachers from a Chilean University in the Maule Region, who were studying the subject of didactics of mathematics in the fifth semester of their curricular career (eight semesters of training). These participants were divided into six working groups (G1, G2, G3, G4, G5, and G6).

The design of the training module included a total of eight sessions of one hour each. In the first two sessions, participants developed level 1 (user) and 2 (reflective user) tasks respectively (individually). In the following sessions, they developed tasks of level 3 (teacher) and 4 (reflective teacher), for which they formed working groups (six working groups). The study presented corresponds to the data collected at level 3, which was conducted in three sessions.

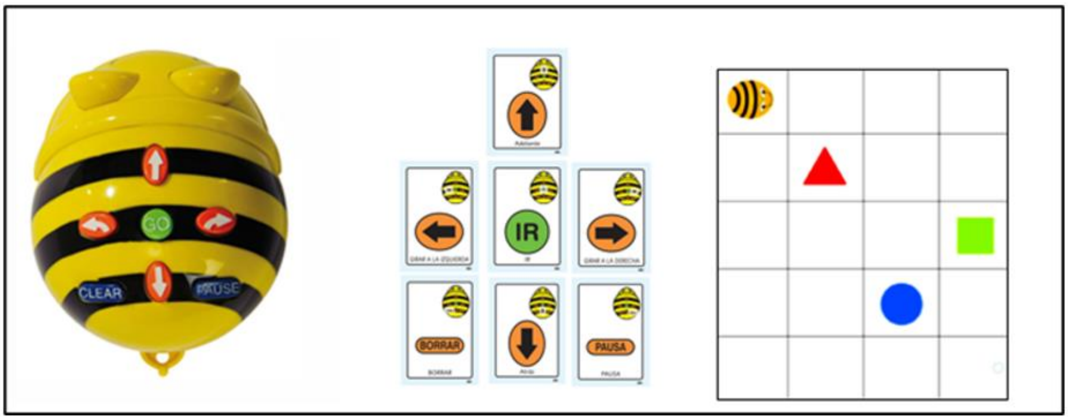

Figure 2. Bee-bot, instruction cards, and example board used

Some of the resources that were used during the training module are shown in **Figure 2**: bee-bot programmable robot, instruction cards, and dashboards with challenges.

Collection and Analysis of Results

The data were collected in two phases, in both, the data were analyzed with the content analysis technique (Cáceres, 2008), for which it was established that:

1. The theory of didactic suitability (its criteria and components) is the theoretical position with which the content was analyzed.
2. Content segments (unit of analysis), phrases, or paragraphs, were individualized to be categorized.
3. Given the dual character of the dimensions presented in the theory of didactic suitability, it will be considered as a rule that a unit of analysis can be categorized into more than one dimension. For example, the following unit of analysis can be categorized into both cognitive and mediational DSC:

> Group 4: What they all have in common is that we have to try to make the tools we use linked to visual elements since their reading and writing abilities are still being built) (reflection of students of group 4, 2020).

Group 4 refers to the use of a type of resource for the development of the class (visual resources), basing its use on the basis of the previous knowledge that the group of students to whom they lead the class has managed to develop (reading and writing skills). In this evidence, for example, it is observed that the group contemplates, in its reflection, the mediational suitability, in particular, the material resources component and the previous knowledge component of cognitive suitability. However, there are no comments referring to the other components of these same suitabilities.

In this way, in the first phase, the participants had to answer the open question how do I teach a computational language (with the bee-bot robot) in a mathematics class? This allowed analyzing their speech, whose data were obtained through a written record prepared collaboratively by each working group. On the other hand, in the second phase, it was requested to design a teaching and learning process based on a planning model that considered three sections:

1. intended learning objective,
2. robotic problem, and
3. description of the teaching and learning process.

This design phase was also addressed through collaborative work, elaborating a written record.

Once the data (written records of both phases) were obtained, a matrix was generated to classify the units of analysis through the six categories established by the theoretical position assumed in this study. The data validity process was performed manually with the expert triangulation technique (Sandín-Esteban, 2000). In this case, one of the authors categorized the units of analysis and presented the analysis matrix to the rest of the authors to assess whether the interpretations coincided. Those units of analysis in which there was no absolute agreement were revised again, taking as reference the components and indicators of the DSC.

It is important to note that the mathematics didactics course aimed at future pre-school teachers in which this training module on CT was developed did not include the teaching of the notion of didactic suitability. In this research, the DSCs are used to analyze the implicit use of these criteria, which work similarly to that carried out in Sala-Sebastià et al. (2022).

RESULTS

This section presents the results obtained in the two phases:

1. open question and
2. design of didactic sequences.

Results from Phase 1: Answer to the Open Question

The open question was addressed by the six working groups, showing that their reflections on how to teach a computational language (with the bee-bot robot) in a mathematics class, are related to the DSC:

1. epistemic,
2. cognitive,
3. interactional,
4. mediational,
5. affective, and
6. ecological.

Below are pieces of evidence from the participants' discourse, related to each category.

In relation to epistemic DSC, two of the six groups of students consider that to teach computational language in a mathematics class it is necessary to design tasks based on problem-solving, which is closely related to the component called process richness:

> Group 5: It is important to think about a meaningful learning experience using logic games and physical movements so that the child thinks about how to solve a certain problem (reflection of students in group 5, 2020).

> Group 6: challenging the child in this case so that he can solve simple problems (reflection of students of group 6, 2020).

There are no comments that can be related to the components: errors, ambiguities, and representativeness of the complexity of the mathematical object to be taught.

In relation to the cognitive DSC, four of the six groups of students consider aspects related to the component of previous knowledge. Some of the reflections refer to the fact that children must have the necessary prior knowledge for the study of computational language in mathematics class with the use of the bee-bot robot:

> Group 1: In the case of the bee-bot, it is necessary to remember in advance the spatial notions of above, below, left, and right, for which the body itself would be used (reflection of students of group 1, 2020).

> Group 6: First, relate the child to what is known to him, from his previous knowledge (forward, backward, right, left) (reflection of students of group 1, 2020).

Likewise, other reflections related to this DSC focus on the component of previous knowledge, specifically, with which the intended learning has a degree of manageable difficulty:

> Group 4: What they all have in common is that we have to try to make the tools we use linked to visual elements since their reading and writing abilities are still being built) (reflection of students of group 4, 2020).

> Group 5: It should also be borne in mind that we must start from the simplest and gradually complicate the requirements that we can give to children. Integrating obstacles between one programming and another, inviting children to look for alternative paths to the goal while dodging obstacles) (reflection of students of group 5, 2020).

> Group 6: challenging the child in this case so that he can solve simple and progressively more complex problems with the bee-bot robot) (reflection of students of group 6, 2020).

There are no comments that can be related to the components of curricular adaptation to individual differences, nor to the components of learning and high cognitive demand of the cognitive DSC.

As for the interactional DSC, it is evident that two of the six groups of students reflect on the teacher-student interaction component:

> Group 2: A computational language is taught starting by explaining to the children the main thing, which in this case would be the arrows, their direction, and the function of each of these, and then move on to practice (reflection of students of group 2, 2020).

> Group 5: Explain the computational language of the robot and its meaning in a playful way or simply use this vocabulary strategically in a precise context, so that the adult when using this language, the child can understand the meaning of the vocabulary in relation to the context in which it is used (reflection of students of group 5, 2020).

There are no reflections of the group of teachers regarding the interaction between students, nor the development of autonomy, nor comments related to formative evaluation.

In relation to mediational DSC, the six groups of students reflected on aspects related to this criterion, specifically, with the material resources component:

> Group 1: When using the bee-bot it becomes essential to use cards to program) (reflection of students of group 1, 2020).

> Group 2: The resources we would use would be a grid, cards, and a robot, but in the same way we consider the use of a large grid on the floor where

you can walk on it, so that in this way the children can check for themselves the programming that is done with the robot, but with their own body and so they can plan the path they need to travel and with it whether to move forward, backward, turn right, left, etc. Along with this, use large programming cards so that everyone can see them) (reflection of students of group 2, 2020).

Group 3: As didactic resources, we have the use of cards, as a basis to then achieve programming in robots) (reflection of students of group 3, 2020).

Group 4: Through cards, we can symbolize computational language, where children can through various games begin to use them and gradually understand their function and meaning) (reflection of students of group 4, 2020).

Group 5: They can also be resources that enhance logical thinking, that can make programming only with cards without the need for the robot) (reflection of students of group 5, 2020).

Group 6: In this case, it is done with fairly simple material to understand as the bee-bot, which can be didactic sheets that allow us to use the bee-bot (directions, pauses, delete, and start). A flat surface grid map can also be elaborated that allows a good displacement of the bee-bot) (reflection of students of group 6, 2020).

There is no evidence of reflection on the number of students, schedule, and classroom conditions, nor on the time that should be allocated for the development of learning.

On the other hand, regarding the affective DSC, five of the six groups of students evidenced reflections related to the needs and interest's component, that is, regarding the need to consider tasks of interest to children and proposal of situations that allow assessing the usefulness of mathematics in everyday life:

Group 1: Then we must apply it to everyday situations so that children become familiar (reflection of students of group 1, 2020).

Group 2: we consider it fundamental that like everything in mathematics this must be taught in context, in real problems (reflection of students of group 2, 2020).

Group 4: It is necessary to design a board simulating a nearby place for the children: In this case, it will be the children who make the tour, this will be done according to the programming indicated by a classmate (reflection of students of group 4, 2020).

Group 5: In addition, it is important to think about a meaningful learning experience using games and physical movements so that the child thinks about how to solve a certain problem, and it makes more sense, for example, to pose an unknown of How can we get the fire truck to the house that burns?, so the child will think how to solve that situation and think about the possible strategies to solve it (reflection of students of group 5, 2020).

Group 6: Then introduce the computational language so that it assimilates concepts, basic ideas, and workflows on programming and CT in a fun way, so that interest is generated (reflection of students of group 6, 2020).

There are no reflections on the attitudes and emotions of the students.

Finally, regarding the ecological DSC, two of the six groups made reflections related to the intra and interdisciplinary connections component:

G1: As well as the carpets with certain themes on which the robot will move, which are related to other subjects.

G5: A grid carpet of a minimum of 4×4 and we can place various elements such as simulating a city, a stadium, school.

There are no comments from future teachers that relate to curricular adaptation, socio-labor utility, and didactic innovation.

In summary, it is observed that in this phase of research the groups of future teachers show in their speech only some of the six DSC and, in addition, they do not contemplate all the components of the DSC that they consider in their reflections. However, when we analyze the discourse of all the groups in a global way, we find evidence related to all the DSC.

Results from Phase 2: Design of Didactic Sequences

In a global way, it is possible to verify that in the design of didactic sequences for teaching and learning mathematics using the bee-bot robot the future teachers make decisions that are related to all the DSC, considering those criteria that were not present in the initial reflection (phase 1: open question).

Table 2 presents a comparison in which the criteria considered by each group (G1, G2, G, G4, G5, and G6) in phases 1 and 2 are appreciated, showing that unlike what happened in phase 1, in the design process (phase 2) all the groups made decisions related to the six DSC.

For reasons of space, the design of the teaching and learning process of the two groups will be analyzed in depth below.

Table 2. Criteria considered by each group in phases 1 and 2

Criterion	Phase 1: Answer to the open question	Phase 2: Didactic sequences design
Epistemic	G5 & G6	G1, G2, G3, G4, G5, & G6
Cognitive	G1, G4, G5, & G6	G1, G2, G3, G4, G5, & G6
Interactional	G2 & G5	G1, G2, G3, G4, G5, & G6
Mediational	G1, G2, G3, G4, G5, & G6	G1, G2, G3, G4, G5, & G6
Affective	G1, G2, G4, G5, & G6	G1, G2, G3, G4, G5, & G6
Ecological	G1 & G5	G1, G2, G3, G4, G5, & G6

Table 3. Characterization of the didactic sequence proposed by the G1

Design elements	Design proposal	Data analysis
Learning objective	Progressively use numbers to count in a programming situation.	*Epistemic DSC:* The mathematical content to be worked on with the use of the robot is decided. *Ecological DSC:* The mathematical content is related to the curricular guidelines for the level
Robotic problem	*Challenge 1:* From the starting point, advance until you reach the pig. *Challenge 2:* From the starting point, advance until you reach the horse. *Challenge 3:* From the starting point, advance until you reach the sheep.	*Epistemic DSC:* A robotic problem is defined *Cognitive DSC:* Different levels of complexity are contemplated in the task (challenges 1, 2, & 3).
Stages & description of the design	**Beginning:** Before starting the activity, the rules will be remembered, & joint agreements will be established to be able to develop an activity of healthy coexistence. A problem will be posted to the children: If I am at the door of the room & I have to reach the furniture that is at the back of the room, how many steps can I take? What paths can I take? What obstacles are there? Which path will I take the least steps? Which way do we take the most steps? **Development:** Working groups are constituted, which will have a carpet whose theme will be "the farm". Each member of the group (three children) will have to solve a challenge of the problem with the collaboration of the other two members. Once the bee-bot reaches the appointed point, the child should mention the characteristics of the animal. If the child does not manage to reach an animal, another companion will be asked for help, to perform new programming. If this help is not enough, sheets with arrows will be delivered so that they can make the journey with these arrows & then program the robot. **Closing:** They will be invited to represent through a drawing the route that each one made with the bee-bots.	*Cognitive DSC:* A collection of previous knowledge. *Ecological DSC:* Interdisciplinary connection (natural sciences). *Interactional DSC:* Dialogue & communication between students are favored. *Ecological DSC:* Interdisciplinary connection (natural sciences). *Affective DSC:* Measures are contemplated to avoid rejection or frustration. *Mediational DSC:* The use of complementary material resources is contemplated. *Epistemic DSC:* The richness of processes through representation.

The design proposed by group 1

Table 3 presents the result of the design proposed by the G1. It should be noted that the robotic problem presented in this table considered the design of the mat or programming scenario shown in **Figure 3**.

As observed in the results of phase 1 of this research, in the proposal of the G1 group, although all the DSC are considered in the design of the didactic sequences, it is observed that not all the components of each DSC are contemplated.

For example, in the interactional DSC, there is no comment related to the development of the autonomy of the students in the realization of the proposed tasks. Nor is reference made to curricular adaptation to individual differences in cognitive DSC.

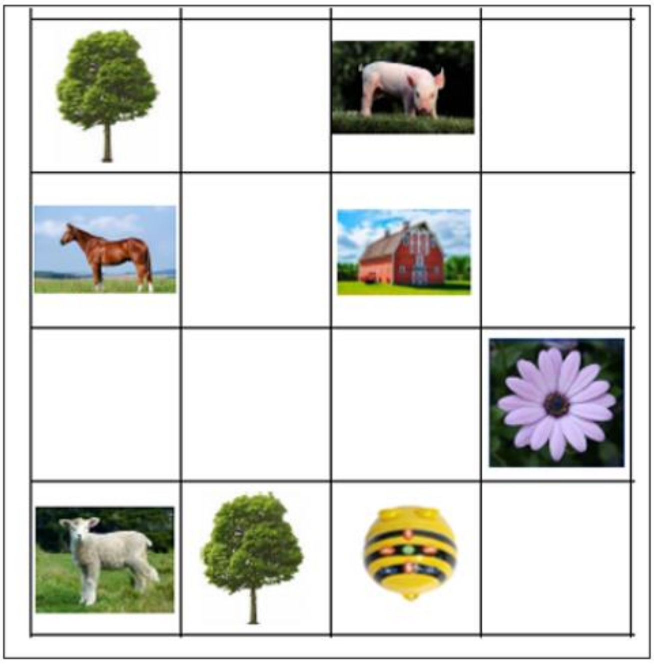

Figure 3. Mat is designed to pose the robotic problem (G1 proposal in 2020)

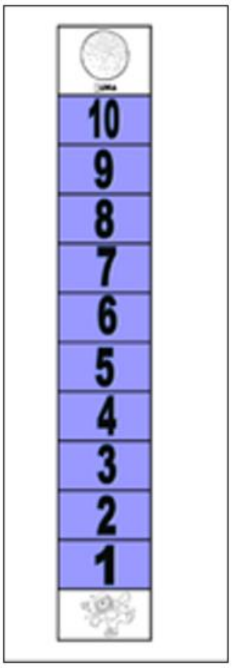

Figure 4. Mat is designed to pose the robotic problem (G4 proposal in 2020)

The design proposed by group 4

The results of the design proposed by the G4, which considered the design of the mat or programming scenario shown in **Figure 4**, are displayed in **Table 4**.

The G4 group's proposal considers all DSCs in the design of the didactic sequences. However, as in the case of G1, it is observed that not all the components of each DSC are contemplated. For example, in the interactional DSC, there is no comment related to how the formative evaluation will be carried out. Nor is reference made to the conditions of the mediational DSC classroom.

DISCUSSION AND CONCLUSIONS

The purpose of the research was to analyze the reflections of future kindergarten teachers when designing didactic sequences to teach mathematics with the use of the bee-bot robot. In order to achieve this objective, it has been decided to carry out an analysis from the perspective of the didactics of mathematics, using the theoretical construct of didactic suitability. With this, we propose an alternative to answer the question: how do we analyze the reflections (of teachers or future teachers) that emerge when designing didactic sequences for CT development in the math class?

Although different authors highlight the importance of considering spaces for teacher reflection in teacher training processes so that they can develop PC at the school level (Estebanell et al., 2018; Kong et al., 2020; Sentance & Humphreys, 2018), there are no studies that have analyzed the reflections that emerge in the framework of training processes or, illustrating theoretical tools that allow analyzing reflections. At the same time, we observe that various investigations use the DSC to investigate the implicit use of these criteria in mathematics teacher training programs that require reflection on their own or others' teaching and learning practices (Breda, 2020; Breda et al., 2021; Moreira et al., 2018). However, no studies analyze the reflections that arise when designing didactic sequences that integrates CT and MT. Therefore, this research extends the investigation in both directions.

In this way, from the perspective of the didactics of mathematics, we can answer the question: In what dimensions (epistemic, cognitive, interactional, mediational, affective, and/or ecological) is the reflection of future kindergarten teachers focused when they say signal a teaching and learning process that articulates the MT and CT?

In the case studied, first of all, we can recognize that the data show that both in phases 1 and 2, the working groups implicitly consider the DSC. This issue was considered a research premise has given to a considerable number of theoretical antecedents that have identified the implicit use of these DSCs in the reflections of teachers or future teachers when they reflect on the teaching practices of mathematics (Hummes et al., 2020; Morales-López & Font, 2019; Seckel et al., 2019, 2021; Seckel & Font, 2020).

Second, we can identify the dimensions on which the participants have focused their reflection during the design of the didactic sequences. On the one hand, we observe that in phase 1, most of the groups of future preschool teachers implicitly use only some of the DSCs, as is the case of G1, G2, G3, G4, and G6.

Table 4. Characterization of the didactic sequence proposed by the G4

Design elements	Design proposal	Data analysis
Intended learning objective	Communicate the process developed in the resolution of specific problems by identifying actions carried out through the technological toy bee-bot.	*Epistemic DSC:* The mathematical content to be worked with the use of the robot is decided.
Proposed problem	The instructions or rules for the game are: 1. They work in pairs. 2. The game will be started by the child who, when rolling the die, obtains the largest number. 3. It always starts from the starting point. 4. Each child programs the robot according to the number obtained when rolling the die. If the robot does not reach the desired point, you need to plan a second attempt with your playmate.	*Interactional DSC:* contemplate making a clear presentation of the instructions of the task. *Mediational DSC:* Plans a distribution of students to encourage collaborative work. In addition, it contemplates the use of additional resources for the development of the activity (dice). *Affective DSC:* Selection of tasks of interest (based on play). Measures are contemplated to avoid rejection through collaborative work (peer support when necessary).
Stages & description of the design	**Beginning (10 minutes):** The educator invites the children to be placed in a semicircle sitting on the floor, indicating that a technological toy called bee-bot will be used, for which she asks do they know technological objects or toys? Subsequently, the bee-bot bee is presented & its operation is made known through projected images. The game to be performed in the activity is also explained, in which a linear numerical carpet will be used, which contains the numbers from 1 to 10 & a die (with numbers from 1 to 6). In the game they must roll the die &, the number that appears will indicate the box to which the bee-bot must arrive. **Development (15 minutes):** The children start the game by rolling the die & in turn programming the bee-bot. During the activity the educator is a mediator, using questions such as: How many boxes do you have to advance? Which arrow should you press? Are you sure? Do you have to move forward or backward? So, other questions that may arise according to the requirements observed during the activity. **Closing:** Finally, he removes the numerical carpet & the bee-bot from the floor & asks do you like the game? What is the name of the bee? How does it work? What did they have to do in the game? Did they manage to reach the goal? how? Then they say goodbye to the bee-bot & it is indicated that at another time it will return.	*DSC cognitive:* The study of the previous knowledge necessary to tackle the task is planned (operation robot communications & given numbers from 1 to 6). *Mediational DSC:* Reflects on the timing of each stage of the teaching & learning design sequences. *Interactional DSC:* Plan types of questions to resolve potential conflicts when approaching the task (both in development & closing).

Only one of the groups, G5, provided evidence of reflection in all the DSCs, a finding that differs from the results obtained in other studies that have analyzed the implicit use of the DSCs when teachers or future teachers reflect on the teaching and learning practices of mathematics (for example: (Morales-López & Font, 2019; Seckel & Font, 2020)). Likewise, we highlight that in this phase, a group (G3) only provided reflection evidence related to one category (mediational). In the latter, based on the nature of the analysis units, it is concluded that the students, at this moment, focused all their attention on the complementary resources to the robot (mat, programming cards, etc.) that they had to consider for teaching–computational language in mathematics class. According to Seckel et al. (2021), this could be due to future teachers' anxiety about using a resource with which they have no previous experience.

Thirdly, in phase 2, when the future preschool teachers prepare to design the didactic sequences, the six groups show the use of all the DSCs. In this way, the groups that in the first phase had not considered some dimensions in their reflections, such as G1, 2, 3, 4, and 6, through the elements required in the design of the didactic sequences (intended learning objective, robotic problem and description of the teaching and learning process), managed to develop reflections in all dimensions. This result can be explained by the fact that future preschool teachers will begin to design a didactic sequence to teach mathematics with the use of robots, they have realized that, for example, in addition to considering the mediational criterion (use of resources) it was necessary to consider other aspects since the teaching and learning process is complex and involves many variables.

However, it is important to note that in both phases, the implicit use of these DSCs did not imply the consideration of all the components that characterize each of the DSCs (Breda, 2020), a result similar to that obtained by Sala -Sebastià et al. (2022) by identifying the implicit DSCs used by future preschool teachers when designing problem-solving tasks and reflecting on them. A possible explanation for this is that the didactic sequences was not implemented, which we value as a limitation of the study since it makes the task of deepening the reflections considering some components of the DSC complex. For example, some components related to the epistemic DSC, such as errors or ambiguities, require an implementation of the design, as do the components of attitudes (students' persistence in carrying out the proposed tasks) and emotions of the affective DSC. Likewise, another limiting or possible cause for not considering some components that characterize the DSC is that the future teachers have not received training with mathematics didactics tools (DSC or others) to reflect on their practice. In this sense, the data is evidence that feeds back into the training program (Breda, 2020; Breda & do Rosário Lima, 2016) and that allows training measures to be taken for the following generations, or else, for the following subjects that this same group of participants will take, since, perhaps, as Perrenaud (2004) states, it is not enough to give the opportunity to reflect, the teacher is also required with tools enabling him/her to direct his/her attention towards relevant aspects of teaching.

Finally, we highlight that future research could focus on the reflections that emerge after observing the implementation of the design, either in real or simulated contexts (Breda et al., 2021). Likewise, it would be interesting to investigate the reflections that emerge after teaching the theoretical construct of the DSC as a tool that guides reflection on practice, as has been addressed in other studies (Giacomone et al., 2018; Godino et al., 2018; Seckel & Font, 2020). In both cases, further research is required, identifying the aspects of the designed class that future teachers consider necessary to modify or improve in a class redesign stage. Likewise, it is necessary to carry out a study that allows defining if it is necessary to broaden the characterization of the DSC to guide the reflection on the teaching and learning practices of mathematics that, in addition, integrate the development of CT.

Limitations of the Study

This study has a few limitations. The main limitation is a lack of an approach to understanding the postures of student teachers. Moreover, the number of classes observed, the number of teachers involved, and our data emerged from one city in Chile. This was due to time constraints and availability of the project resources, and the time scale. Further cross-cultural studies from non-Latin countries would strengthen the reliability of our results.

Practical Contributions

One of the practical contributions of the study is to point out the importance of designing and implementing cycles or training programs for initial teacher trainees, with the use of pedagogical robots, which contemplate the six dimensions of didactic suitability (DSC). This type of training could increase the level of didactic analysis of future teachers since when designing, implementing, and reflecting on teaching and learning process with the use of pedagogical robots using all the dimensions of the DSC, leads the future teacher to a level of more complete and balanced didactic analysis (Esqué de los Ojos & Breda, 2021; Hernández-García & Breda, 2022).

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