Revista de Psicodidáctica 26 (2021) 143–151

Revista de Psicodidáctica

www.elsevier.es/psicod

Original

Education intervention using a ground robot with programmed directional controls: observational analysis of the development of computational thinking in early childhood education ☆

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A R T I C L E   I N F O

Article history:
Received 31 August 2020
Accepted 10 March 2021
Available online 7 April 2021

Keywords:
computation
robotics
pre-primary school
observational methodology
T-patterns

A B S T R A C T

The present work presents an intervention proposal for the development of computational thinking in early childhood education, through the use of a ground robot with programmed directional controls. Within the use of observational methodology, an observation system has been designed that allows the analysis and interpretation of the behavior displayed in the performance of the intervention proposal. The reliability of the observation system has been guaranteed in the form of inter-observer agreement, calculated using Cohen's (1960) Kappa coefficient. Within the theory of generalizability, the measurement plan [Categories] [Steps]/[Participants], has allowed to verify a high precision reliability of the generalization of the results. The operability of the observation system has been reflected in the regular behavior structures (T-patterns) detected -through the Theme software-, which have allowed characterizing difficulties in the assimilation of an incipient computational language related to the ability of spatial orientation and the sequencing capacity of children -situations involving turning and number of commands used in the sequence-.

Propuesta de intervención mediante un robot de suelo con mandos de direccionalidad programada: análisis observacional del desarrollo del pensamiento computacional en educación infantil

Palabras clave:
computación
robótica
Educación Infantil
metodología observacional
T-patterns

R E S U M E N

El presente artículo presenta una propuesta de intervención para el desarrollo del pensamiento computacional en Educación Infantil, mediante un robot de suelo con mandos de direccionalidad programada. En el seno de la metodología observacional, se ha diseñado un sistema de observación que permite el análisis e interpretación de la conducta desplegada en el desempeño de la propuesta de intervención. La fiabilidad del sistema de observación se ha garantizado en forma de concordancia interobservadores, calculada a través del coeficiente Kappa de Cohen (1960). En el seno de la teoría de la generalizabilidad, el plan de medida [Categorías] [Steps]/ [Participantes], han permitido constatar una elevada fiabilidad de precisión de generalización de los resultados. La operatividad del sistema de observación ha quedado reflejada en las estructuras regulares de conducta (T-patterns) detectadas -mediante el software Theme-, que han permitido caracterizar dificultades en la asimilación de un lenguaje computacional incipiente relacionadas con la capacidad de orientación espacial y la capacidad de secuenciación del niño -situaciones que implican giro y número de comandos empleados en la secuencia-.

PII of original article:S1136-1034(21)00035-6.

☆ Please cite this article as: Terroba M, Ribera JM, Lapresa D, Anguera MT. Propuesta de intervención mediante un robot de suelo con mandos de direccionalidad programada: análisis observacional del desarrollo del pensamiento computacional en Educación Infantil. Revista de Psicodidáctica. 2021;26:143–151. https://doi.org/10.1016/j.psicod.2021.03.001

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Introduction

Wing (2006) introduced the concept of computational thinking and defined it as the process of solving problems, designing systems, and understanding human behavior, based on the fundamental concepts of computer science. Wing (2008) adds that the solutions posed to computational thinking problems must be able to be represented in such a way that they can be undertaken by some information processing tool. Aho (2012), specifies the definition of computational thinking to pose problems whose solutions can be represented by steps and algorithms. *Google for Education* (2015) specifies four phases of computational thinking: decomposition, pattern recognition, abstraction, and algorithm writing. Numerous studies show that, from childhood, computational thinking benefits mathematical reasoning and problem solving skills (del Olmo-Muñoz et al., 2020; Diago et al., 2018; Fessakis et al., 2013; Kazakoff et al., 2013; Lee et al., 2011; Sullivan & Bers, 2016). Solving problems through computational thinking allows students to break down a problem into simpler parts to find possible solutions -or solution algorithms-, favoring the capabilities of analysis, reasoning and effective communication of results (Clements & Sarama, 1997; Elkin et al., 2014; Papert, 1981; Wing, 2006).

Robotics can become a very attractive interdisciplinary teaching system for student learning, generating playful experiences that incorporate problem solving and logical reasoning (Bers, 2018; Bers et al., 2014; Mercader et al., 2017). Educational robotics is a discipline whose objective is to create and operate robots and programs suitable for educational purposes (Bers, 2008; Bers et al., 2019). The *Science, Technology, Engineering and Mathematics* (STEM) methodology -an integrative perspective with the interest of solving practical problems applied to the real world- promotes learning in a natural and playful way (Bers et al., 2019). The educational robots that are currently designed for Early Childhood and Primary Education students become tools that promote the understanding of abstract mathematical concepts in a manipulative way (Alsina, 2017) -as have been other materials traditionally used: blocks, beads, balls, strips, multi-cubes, etc. (Resnick et al., 1998)-. Favoring the logical, precise and orderly thinking of students, and increasing their problem solving capacity (Elkin et al., 2014) in the real and changing world around them. One possible resource for solving problems through computational thinking in Early Childhood Education is to have ground robots with programmed directionality (Diago et al., 2018). The use of technological interfaces of programmed directionality facilitate the development of spatial orientation capacity (Città et al., 2019; Kalelioğlu, 2015; Pérez & Diago, 2018; Sarama & Clements, 2004), an essential component for the management of daily life situations in students (Clements & Sarama, 1997; Fessakis et al., 2013; Jiménez-Gestal et al., 2019). The study of the behaviors that occur in the processes of decomposition of problems into simpler challenges, the search for the similarities they have in common, the focus on important aspects ignoring irrelevant details and the development of rules or sequences of problem solving -algorithms-, is presented as a work of great interest for the analysis of the development of computational thinking.

This article has two objectives: one to discipline and a methodological one. In terms of discipline, a proposal for intervention is presented based on a collection of problems that favors the development of computational thinking, using a ground robot with programmed directional controls. In the methodological field -within observational methodology-, an observation system has been designed -which provides evidence of content validity, reliability and generalizability- that allows the analysis and interpretation of the behavior displayed in the performance of the intervention proposal. The operativity of the observation system will characterize the performance of children in the third year of Early Childhood Education -5 years old- in solving each of the problems raised, showing the difficulties in assimilating an incipient computer language.

Method

The present work has been developed through the use of observational methodology (Anguera, 1979), and is multimethod, since some elements typical of quasi-experimental methodology are used secondarily (Arnau, 2001), in addition to mixed methods (Anguera, Blanco-Villaseñor et al., 2018). According to Anguera et al. (2011), the observational design is: nomothetic, since the object of observation is the behavior of 24 third-year students in early childhood education who do not act as a class; intersessional monitoring, along the different steps ($n = 7$) that make up the intervention proposal; intra-sessional monitoring, since the behaviors under study are recorded frame to frame throughout the performance of each step; and multidimensional, as shown by the different criteria defined in the observation instrument. Observation is direct except in the Instruction dimension of the teacher, which is indirect since it involves verbal information (Anguera, Portell et al., 2018). Observation is participant, since the first author of the work interacts with the participants.

Participants

In this work, an intentional sampling has been carried out (Anguera et al., 2019), facilitated by the interest of the Center in the development of the project. The participants were 24 students (13 girls, 54.16%; 11 boys, 45.83%) from the 3rd grade of early childhood education -5 years old- of the CEIP La Guindalera de Logroño, La Rioja, Spain -center located in a newly created residential neighborhood, with only 4.07% of the student body belonging to disadvantaged ethnic or sociocultural minorities-. Of these, eleven students ($M = 5.624$, $SD = 0.29$) passed the selection test and made the intervention proposal (seven girls, 63.63%; four boys, 36.36%). This work has the relevant informed consents and the approval of the Research Ethics Committee of the University of La Rioja (file nº CE-08-2020).

Instrument

The observation instrument has been developed *ad hoc*, and is a combination of a field format and systems of categories (Table 1). In each of the criteria of the observation instrument, category systems have been created, which meet the conditions of exhaustiveness and mutual exclusivity. Taking into account the considerations of Anguera et al. (2007), an initial version was first constructed based on the theoretical revision carried out. The construction of the observational tool was developed from a dynamic process of initial formulation of tentative categories subsequently modified according to an empirical-inductive strategy and then, again, according to a theoretical-deductive strategy. When the preliminary version of the proposed observation instrument was ready, it was submitted to the caution test. This phase was carried out with first, second and third year early childhood education students who are not part of the observational research sample. An incomplete balancing of equivalent groups was designed (Arnau, 2001): Step 1, 1st grade student of early childhood education; Step 2, 3rd grade student; Step 4, 2nd year student; Step 6, 1st grade student of early childhood education; Step 7, 3rd grade student; bearing in mind that, due to their similarity, only one of the steps 2 and 3 (trajectory on the red guideline marked in the grid) and another of the steps 4 and 5 (trajectory without guideline with obligatory waypoints and determined start and end) was selected. After the corresponding records were made and no new categories were detected in any

Table 1
Summary structure of the observation instrument: criteria, categories and codes

Criteria	Categories and codes
Step	Step 1 (TP1); step 2 (TP2); step 3 (TP3); step 4 (TP4); step 5 (TP5); step 6 (TP6); step 7 (TP7)
Phase	Determination of the previous route (DPR); card choice (CC); movement associated with the robot to the choice of cards (MARC); drive (DR); introduction into the robot (IR)
Intra-phase attempt	First attempt (A1); second attempt (A2); third attempt (A3)
Attempt/phase efficacy	Solves (S); does not solve (NS); matches the card phase but does not solve (MCP); solves but does not agree with the previous determination of the route (SNPP)
Displacement	First displacement (D1); second displacement (D2); third displacement (D3) . . . twenty-forth displacement (D24)
Spatial information of the displacement	Forward (FO); back (BA); left turn (LT); right turn (RT)
Orientation of the robot compared to its initial position	Same orientation (RIPS); left lateral orientation (RIPL); right lateral orientation (RIPR); mirrored position (RIPM)
Orientation of the robot compared to the child	Same orientation (RCS); left lateral orientation (RCL); right lateral orientation (RCR); mirrored position (RCM)
Adaptation of behavior to the problem posed	Adaptive (ADAP); non-adaptive (NOAD)
Withdrawn displacement	Previous displacement (PD); up to the first error (DFE); all (AD); the card that is incorrect in the sequence (DIC); an incorrect sequence card (DAIC); a correct sequence card (DCC)
Teacher instruction	The teacher redirects/promotes reasoning (TRR); the teacher redirects/places the student for inaction (TRI); the teacher fixes the error with a question (TFE); the teacher explicitly states the mistake made, but does not give an answer (TENA); the teacher explicitly states the mistake made and gives an answer (TEGR)

criterion, the caution test was passed, assuming the catalogue-type lists as repertoire-type lists (Anguera & Izquierdo, 2006), with the presumption of exhaustiveness of the built category systems in the field format.

Procedure

Firstly, a selection phase of the participants who went on to the intervention proposal was carried out. In this phase, three sessions were held with the entire class group: a first one, consisting of reading and dramatizing the story that constitutes the symbolic framework of the study (Gowen, 1995); a second psychomotor session, in which spatial orientation tasks were performed on squares marked with electrical tape; a third session -individual-, with five problems to be solved in a motor way similar to those of step 1 of the intervention proposal. All these sessions were filmed with the aim of avoiding the reactivity bias of the students during the observation sessions (Anguera, 2003). The correct resolution of the five basic tasks that make up the selection test guarantee that the participants have a capacity for spatial organization and problem solving that allows them to face the entire intervention proposal (the seven steps). The students ($n = 11$) who correctly solved the five proposed tasks, began to carry out the intervention proposal designed to develop computational thinking in early childhood education. The intervention proposal consists of seven problems, designed as steps of increasing difficulty (see Figure 1).

The previously defined intervention protocol that has guided the development of the intervention proposal is detailed below. The placement of grids, card box, teacher and initial position of the student (and the robot) was predefined (see Figure 2). Each step began with the explanation of the challenge to be solved, the presentation of the cards that could be used and the conditions that had to be met to solve the step. The teacher's interaction with the student -whose objective is summarized in encouraging and promoting the response to the problem posed- was developed under the following premises: not correcting wrong answers; not conditioning a certain response; not interrupting or intervening in the verbalizations of the students; encouraging at the end of each decision so that the student continues with the next step; in case the students were a minute without advancing or taking a step, the teacher, by means of questions, facilitated the analysis of the situation for the student -she never gave the correct answer-.

To solve each step the participants had three attempts. Participants could start a new attempt as long as the fifth minute had not passed since the resolution of the problem began. All the students carried out the resolution of the seven problems or steps posed regardless of the answer given in them (adaptive or non-adaptive).

Recording and coding

Recording was made in order, first of participants -from one to eleven- and from steps -from one to seven-. In total, there are 77 observation sessions corresponding to the resolution of each of the seven steps of the intervention proposal by the eleven selected participants. For the recording and coding of the 77 data packages that make up the observational sampling of this work, the LINCE software, version 1.2.1 (Gabin et al., 2012) has been used (see Figure 2).

According to the classic classification of Bakeman (1978), Type IV, concurrent and time-base data have been recorded in the present work. In other words, the data incorporate the order and duration parameters and they co-occur -as can be seen from the multidimensional nature of the observational design, and from the fact that the observation instrument is a combination of a field format and category systems-. Also, according to Bakeman & Quera (1995), the data type is multievent.

Data quality

Intersessional consistency has been guaranteed based on satisfaction, in each of the observation sessions, with the following list of minimums: time slot (from 10 to 12 hours, avoiding the first and last hours of the morning), the half-group room of the Center for Early Childhood Education; disposition of materials and participants; teacher and intervention protocol; teacher who handled the filming of the sessions; all participants successfully completed the selection test; all participants wore two cuffs -one green for the right hand and one red for the left hand-.

Data reliability

Cohen's (1960) Kappa coefficient was used to determine interobserver agreement using the LINCE software. Two observers have carried out the recording and coding of the data. One of them, the first author of this work who has actively participated in the development of the observation system. The second observer has followed a training process -respecting the stages proposed by Arana et al. (2016)- advancing from a theoretical process (the conceptual explanation of the observation instrument),

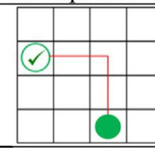
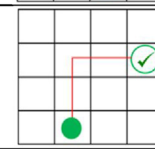
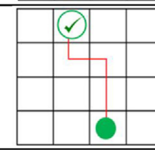
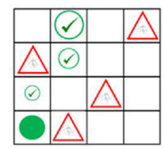
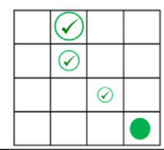
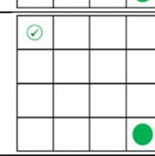
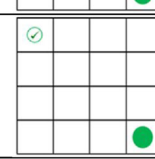
Step	Challenges	Graphical representation
Step 1	Route to be carried out in a motorized way, following previously established orders, to reach the protagonist of the symbolic game	
Step 2	Problem to be solved by the programmed directional floor robot. The robot must travel the indicated path to reach the protagonist of the symbolic game	
Step 3	Problem to be solved by the programmed directional floor robot. Problem that includes two turns to get to the protagonist of the symbolic game	
Step 4	Problem to be solved by the programmed directional floor robot. No marked path is presented. There are some conditions that you must meet on your journey: pick up the small, medium and large protagonists in order. Passing through spaces where there is a danger sign is prohibited	
Step 5	Problem to be solved by the programmed directional floor robot. No marked path is presented. There are some conditions that you must meet on your journey: pick up the small, medium and large protagonists in order	
Step 6	Problem to be solved by the programmed directional floor robot. Problem in which the robot has to travel the shortest path to reach the protagonist of the symbolic game	
Step 7	Problem to be solved by the programmed directional floor robot. Problem in which the robot has to travel the longest path to reach the protagonist of the symbolic game	

Figure 1. Constitutive challenges of the intervention proposal.

theoretical-practical (the operation of the observation instrument within the record and coding software, LINCE) and ending with a practical application of the observation within the record program with four observation sessions corresponding to four steps solved by a participant out of sampling. After obtaining a Cohen's Kappa greater than 0.80, between the records of the four steps by both observers, the training process was terminated. Subsequently, both observers proceeded to record the seven steps of participants nº 3 and nº 13 (18.18% of the observational sampling).

Generalizability of results

Data quality has also been addressed from the Generalizability Theory framework (Cronbach et al., 1972), using the SAGT software, version 1.0, (Hernández-Mendo et al., 2016), based on Blanco-Villaseñor & Escolano-Pérez (2017): (1) *Observation plan*. The facets have been arranged in a "crossed" manner: Categories (C), which has 65 levels -the categories corresponding to the variable criteria of the observation instrument-; Steps (S), with seven levels; and Participants (J), with eleven levels; (2) *Estimation plan*. In all three facets, an estimate will be made for an infinite population; (3) *Measurement plan*. The measurement plan has been carried out: [Category] [Step]/[Participants], to assess the generalizability of the results based on the number of participants who have developed the intervention proposal; and, (4) *Optimization plan*. It has not been necessary to develop the optimization plan of the present design, as can be seen in the results section.

Data analysis

To show the potential of the designed observational tool, due to its informative potential, one of the most relevant analysis techniques that are currently used to conduct diachronic behavior analyzes has been used (Santoyo et al., 2020): the T-pattern detection using THEME software. Specifically, the free version (v.6 Edu) has been used. THEME software is based on a powerful algorithm developed by Magnusson (1996, 2000) that allows to detect regular behavior structures hidden in the record. Although the main contribution of THEME is the detection of T-patterns, the *software* also offers the possibility of detecting sequential structures under the order parameter -from a constant duration assignment to each unit of behavior-, which provides some very relevant possibilities for the analysis of sequentiality since it allows us to deduce if the behaviors are consecutive or if there are gaps -interspersed behaviors- between the detected multi-events (Lapresa, Anguera et al., 2013; Lapresa, Arana et al., 2013).

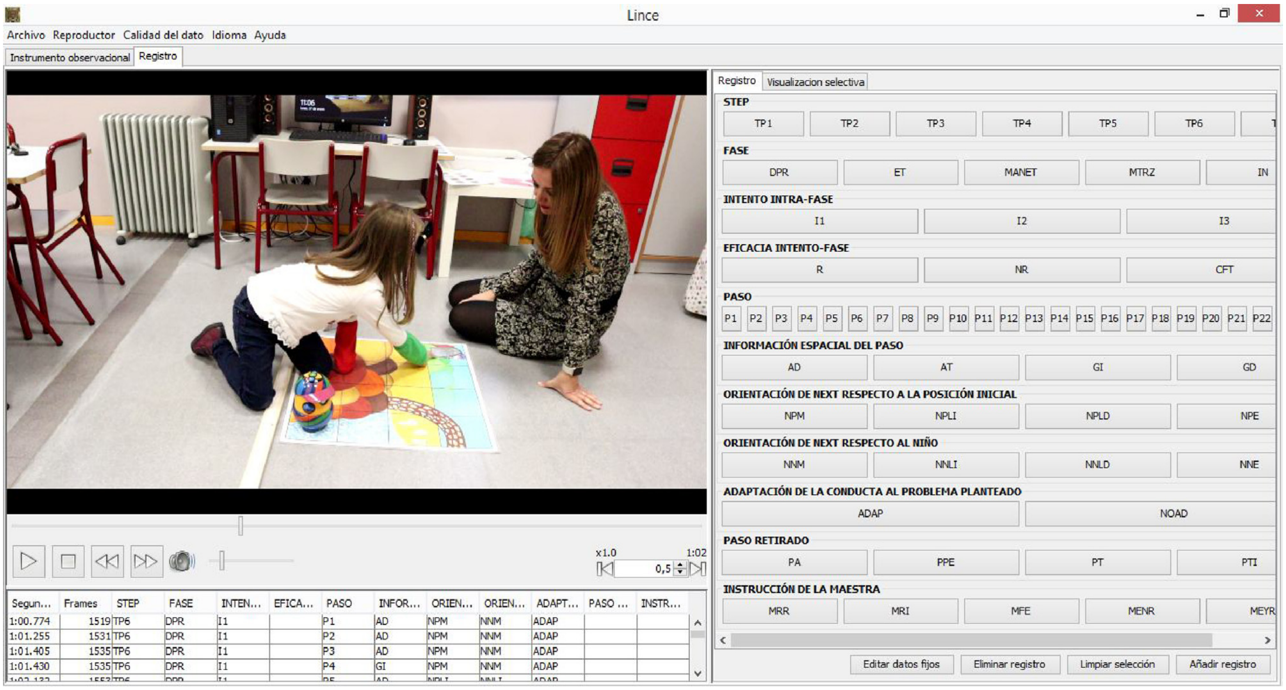


Figure 2. Image of a moment of the record and coding of the data package corresponding to participant 2, *step* 6, within the software LINCE, version 1.2.1.

The search parameters detailed below have been selected (see reference manual: PatternVision Ltd & Noldus Information Technology bv, 2004): (a) minimum occurrences: an occurrence frequency equal to or greater than 2 has been set; (b) level of significance of 0.005, so the probability percentage of accepting a critical interval due to chance is 0.5%; (c) redundancy reduction: by setting a value of 90, it is intended that if more than 90% of the occurrences of a new detected pattern begin and end at almost the same time as the already detected patterns, the new pattern is discarded; (d) the *free* T-patterns type has been used; and, (e) validation of results: the results have been validated by randomizing the data on 100 occasions -by the *shuffling* procedure- and accepted only those patterns whose probability of being accepted due to chance is equal to 0. Once the search was carried out, a series of qualitative filters (Amatria et al., 2017) were applied for the selection of T-patterns that reflect errors in the different phases involved in solving the problem.

Results

Concordance between observations

The Cohen (1960) Kappa coefficient values that provide reliability information, in agreement between data packages, are shown in Table 2. In all the data blocks used for the reliability determination, a consideration of the agreement has been obtained, from the reference values set by Landis and Koch (1977, p. 165), from "almost perfect" (Cohen's Kappa greater than 0.80).

Generalizability of results

Table 3 presents the results of the design [Categories] [*Steps*]/[Participants]. Their analysis reveals that the variability is associated with the categories facet: 35.721%, and with the interaction [step] [categories] with 46.396%. The analysis of the generalizability coefficients in this design structure determines that a reliability of the precision of the generalizability is = 0.989 -the same value of the relative generalizability coefficient and the absolute- is achieved. This result allows us to endorse the number of participants with which this research has been carried out.

From the information contained in the records of each step

The record corresponding to participant 1 in step 1 (see Table 4), which includes the way in which the planned step is solved, serves as an example of the operation of the observation instrument. In this case, the resolution proposed corresponds to the graphic representation of the ideal solution of the step 1 (see Figure 1).

From the information contained in the cluster of detected T-patterns

Due to their relevance, the T-patterns detected by the THEME software (v.6 Edu) are exposed, according to the search parameters and to the qualitative filter of the predetermined selection. This qualitative filter refers to the presence, in the detected T-patterns, of non-adaptive behaviors -that is, those in which the step taken by the student in the corresponding sequential element does not lead to the resolution of the problem-. The presence of these non-adaptive behaviors provide relevant information about the child's difficulties regarding the assimilation of an incipient computational language. Taking into account the issue of degradation (see Lapresa et al., 2015), the T-pattern that includes a greater number of participants and that has a greater number of constitutive multi-events has been selected. Table 5 shows the order number of each selected T-pattern, the pattern in chain format, the participants who perform them, and the average of internal intervals between multi-events -so that if the internal interval is equal to 1, there is certainty that the behaviors reflected in the pattern are consecutive-.

Discussion

An intervention proposal has been designed for the development of computational thinking in early childhood education, through the use of a ground robot with programmed directional

Table 2
Cohen's Kappa coefficient for dimensions and steps in participant records with ID3 and ID13

	Step 1		Step 2		Step 3		Step 4		Step5		Step 6		Step 7	
	ID3	ID3	IDI3	ID13	ID3	ID13	ID3	ID13	ID3	ID13	ID3	ID13	ID3	ID13
Step	1	1	1	1	1	1	1	1	1	1	1	1	1	0.0
Phase	1	1	1	1	1	1	1	1	1	1	1	1	0.97	1
Int. intra-fase	1	1	1	1	1	1	1	0.91	1	1	1	1	1	0.96
Efficacy	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Displacement	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spatial info.	1	1	1	1	1	1	1	1	1	1	1	0.92	1	1
Robot-Initial p	1	1	1	1	1	1	1	1	0.93	0.94	1	0.93	1	1
Robot-child	1	1	1	0.84	1	1	0.92	1	0.93	0.88	0.92	0.93	1	0.97
Adaptation	1	1	1	1	1	1	1	1	1	1	1	1	0.84	1
Wtihdrawn dis	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Teacher instr.	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total record	1	1	1	0.98	1	1	0.99	0.99	0.98	0.98	0.99	0.98	0.98	0.90

Table 3
Results corresponding to the generalizability design [Category]/[Participant]

Sources of variation	Square sum	Degrees of freedom	Mean square	%	Standard error
[participant]	1096.67	10	109.66	0.16	0.10
[step]	24645.15	6	4107.52	7.22	2.87
[participant][step]	3320.06	60	55.33	1.05	0.15
[categories]	149481.43	64	2335.64	35.72	5.29
[participant][categories]	5443.12	640	8.50	0.41	0.07
[step][categories]	142334.47	384	370.66	46.39	2.42
[participant][step][categories]	24742.87	3840	6.44	9.02	0.14

Table 4
Record corresponding to participant 1, step 1. Time is expressed in frames

TIME (frames)	EVENT
1251	TP1,CC,A1,D1,FO,RIPS,RCS,ADAP
1388	TP1,CC,A1,D2,FO,RIPS,RCS,ADAP
1491	TP1,CC,A1,D3,LT,RIPS,RCS,ADAP
1691	TP1,CC,A1,D4,FO,RIPL,RCL,ADAP
1922	TP1,CC,A1,D5,FO,RIPL,RCL,ADAP
1974	TP1,CC,A1,S
2497	TP1,DR,A1,D1,FO,RCS,ADAP
2575	TP1,DR,A1,D2,FO,RCS,ADAP
2605	TP1,DR,A1,D3,LT,RCS,ADAP
2641	TP1,DR,A1,D4,FO,RCR,ADAP
2672	TP1,DR,A1,D5,FO,RCR,ADAP
2698	TP1,DR,A1,S

controls. Each of the steps that make up the proposal represents a challenge that promotes logical reasoning (Bers, 2018), contextualized in a playful framework of symbolic play (Gowen, 1995). For the evaluation of the intervention proposal, the observational methodology was used (Anguera, 1979), since the fundamental requirements of habitual behavior, performance in a natural context and perceptivity of the behaviors performed are fulfilled (Anguera, 2003). Another characteristic element of the observational methodology is that the observation instrument used is not standard, but has been prepared *ad hoc* for this study, based on a dynamic process of transfer between the theoretical framework and reality, and having overcome the caution test that allows defining the repertoire type list that makes up each category system (Anguera et al., 2007).

Regarding the reliability of the observation system, the results obtained reveal a high interobserver agreement calculated using the Cohen (1960) Kappa coefficient. Consideration of the ñear perfectägreement corresponding to Cohen's Kappa values greater than 0.80 has been obtained from the classic Landis and Koch (1977) reference values. Regarding generalizability, the measurement plan [Categories] [Steps]/[Participants], has made it possible to ensure that, with the number of participants analyzed, a high reliability of the precision of the generalization is achieved (0.989), which endorses the homogeneity of the behavior displayed by the participants. The operability of the developed observation system is reflected, on the one hand, in the records corresponding to each data package of each participant in each step; and, on the other, in the detected T-patterns, using the THEME software. And it is that, it is in the diachronic analyzes where the observational methodology shows us all its potential (Anguera et al., in press).

Regarding the records corresponding to each data package, the observation instrument designed allows us to represent the child's behavior and his interaction with the teacher in a linear -temporary- and schematic way. This representation facilitates the understanding of each of the steps carried out by the participants in carrying out each of the steps that constitute the intervention proposal. The interpretation of the detected regular behavior structures (T-patterns), constitutes a magnificent reflection of the concrete difficulties of assimilation of an incipient computational language in 5-year-old students; and of the possibilities of self-evaluation of the process that provides the resolution of problems through computational thinking. The specific difficulties of assimilating an incipient computational language in 5-year-old students will be characterized from the errors reflected in the T-patterns, related to the spatial orientation capacity and the sequencing capacity of the child -either in relation to situations involving turning or the number of cards (commands) used in the sequence-.

Each one of the steps proposed supposes a requirement of the spatial orientation capacity of the child -compared to himself, compared to the robot, or compared to a reference cell-. The difficulty of the 5-year-old students to solve the displacement that implies an orientation of the robot different from their own has been evidenced. (a) In step 7, the only step in which a mirror orientation has been recorded between the child and the robot, T-patterns have been detected that show errors committed, when the child's orientation is contrary to that of the robot: the T-pattern with order number 7.2 shows how participants 4 and 5 correctly carry out the previous round phase but in the card selection phase, in this described situation, they make a mistake; the T-pattern with order number 7.1, reflects how participants 4 and 9 start a second attempt in the card choice phase -after an intervention by the teacher in which she promotes the student's reasoning- but they fail in the step in which the robot's orientation is contrary to that of the child;

Table 5
T-patterns detected with previously defined search parameters and selection criteria

Order Nº	Chain format pattern	Participants	Mean of the internal Interval
1.1.	(((tp1,cc,a1,d6,fo,ripl,rcl,noad tp1,cc,a1,ns)(tp1,dr,a1,p1,fo,rcs,adap tp1,dr,a1,d2,fo,rcs,adap))(((tp1,dr,a1,ns tp1,cc,a2,dic)(tp1,cc,a2,r tp1,dr,a2,ad))((tp1,dr,a2,d1,fo,rcs,adap (tp1,dr,a2,d2,fo,rcs,adap tp1,dr,a2,d3,lt,rcs,adap))((tp1,dr,a2,d4,fo,rcr,adap tp1,dr,a2,d5,fo,rcr,adap) tp1,dr,a2,r))))	3 and 8	All 1
1.2.	(tp1,cc,a1,d6,fo,ripl,rcl,noad tp1,cc,a1,ns)	3, 8 and 11	All 1
2.1.	((tp2,cc,a1,d1,fo,rips,rcs,adap tp2,cc,a1,d2,fo,rips,rcs,adap)((tp2,cc,a1,d6,fo,ripr,rcr,noad (tp2,cc,a1,ns tp2,ir,a1,d1,fo,rips,rcs,adap))((((tp2,ir,a1,d2,fo,rips,rcs,adap tp2,ir,a1,d5,fo,rips,rcs,adap)(tp2,cc,a2,trr tp2,cc,a2,pd))(tp2,ir,a2,ad tp2,ir,a2,d1,fo,rips,rcs,adap))(tp2,ir,a2,d2,fo,rips,rcs,adap tp2,ir,a2,d5,fo,rips,rcs,adap))))	8 and 11	1-4-1-1-1-3-3-1-2-1-1-3
3.1.	(((tp3,cc,a1,d1,fo,rips,rcs,adap tp3,cc,a1,d2,fo,rips,rcs,adap) tp3,cc,a1,d3,lt,rips,rcs,adap)(tp3,cc,a1,d4,fo,ripl,rcl,adap tp3,cc,a1,d5,fo,ripl,rcl,noad))	1, 3 and 5	All 1
3.2.	((tp3,cc,a1,d3,lt,rips,rcs,adap ((tp3,cc,a1,d4,rt,ripl,rcl,noad tp3,cc,a1,d5,fo,rips,rcs,noad)(tp3,cc,a1,ns tp3,ir,a1,d1,fo,rips,rcs,adap)))((tp3,ir,a1,d5,fo,rips,rcs,adap tp3,ir,a1,mcp)((tp3,cc,a2,dfe (tp3,cc,a2,d4,fo,ripl,rcl,adap tp3,ir,a2,ad))(tp3,ir,a2,d1,fo,rips,rcs,adap (tp3,ir,a2,d3,lt,rips,rcs,adap tp3,ir,a2,d4,fo,rips,rcs,adap)))))	8 and 10	1-1-1-1-1-1-2-1-2-1-1
4.1.	((tp4,cc,a1,d2,rt,rips,rcs,adap tp4,cc,a1,p3,fo,ripr,rcr,adap) tp4,cc,a1,d4,fo,ripr,rcr,noad)	4, 7, 8, 9, 10 and 11	All 1
5.1.	(((tp5,cc,a1,d2,lt,rips,rcs,adap tp5,cc,a1,d3,fo,ripl,rcl,adap)((tp5,cc,a1,d4,rt,ripl,rcl,noad tp5,cc,a1,d5,fo,rips,rcs,noad)(tp5,cc,a1,d6,fo,rips,rcs,noad tp5,cc,a1,ns)))((tp5,ir,a1,d1,fo,rips,rcs,adap ((tp5,ir,a1,d2,lt,rips,rcs,adap tp5,ir,a1,d3,fo,rips,rcs,adap)(tp5,ir,a1,d5,fo,rips,rcs,adap tp5,ir,a1,mcp)))((tp5,ir,a2,ad tp5,ir,a2,d1,fo,rips,rcs,adap)((tp5,ir,a2,d2,lt,rips,rcs,adap tp5,ir,a2,d3,fo,rips,rcs,adap) tp5,ir,a2,d4,fo,rips,rcs,adap))))	4 and 7	1-1-1-1-1-1-1-1-2-2-8-1-1-1-1
5.2.	((tp5,cc,a1,d4,fo,ripl,rcl,adap tp5,cc,a1,d5,fo,ripl,rcl,noad)(((tp5,cc,a1,ns tp5,ir,a1,d1,fo,rips,rcs,adap)(tp5,ir,a1,d2,lt,rips,rcs,adap tp5,ir,a1,d3,fo,rips,rcs,adap))((tp5,ir,a1,d4,fo,rips,rcs,adap tp5,ir,a1,d5,fo,rips,rcs,adap)(tp5,ir,a1,mcp tp5,cc,a2,ns))))	1 and 9	1-1-1-1-1-1-1-1-6
6.1.	(((tp1,cc,a1,d6,fo,ripl,rcl,noad tp1,cc,a1,ns)(tp1,dr,a1,p1,fo,rcs,adap tp1,dr,a1,d2,fo,rcs,adap))(((tp1,dr,a1,ns tp1,cc,a2,dic)(tp1,cc,a2,r tp1,dr,a2,ad))((tp1,dr,a2,d1,fo,rcs,adap (tp1,dr,a2,d2,fo,rcs,adap tp1,dr,a2,d3,lt,rcs,adap))((tp1,dr,a2,d4,fo,rcr,adap tp1,dr,a2,d5,fo,rcr,adap) tp1,dr,a2,r))))	3 and 9	1-1-1-2-1-4-1-2-1-1-1-2-1
7.1.	(tp1,cc,a1,d6,fo,ripl,rcl,noad tp1,cc,a1,ns)	4 and 9	10-1-2
7.2.	((tp2,cc,a1,d1,fo,rips,rcs,adap tp2,cc,a1,d2,fo,rips,rcs,adap)((tp2,cc,a1,d6,fo,ripr,rcr,noad (tp2,cc,a1,ns tp2,ir,a1,d1,fo,rips,rcs,adap))((((tp2,ir,a1,d2,fo,rips,rcs,adap tp2,ir,a1,d5,fo,rips,rcs,adap)(tp2,cc,a2,trr tp2,cc,a2,pd))(tp2,ir,a2,ad tp2,ir,a2,d1,fo,rips,rcs,adap))(tp2,ir,a2,d2,fo,rips,rcs,adap tp2,ir,a2,d5,fo,rips,rcs,adap))))	4 and 5	3-1-34-4

(b) Two T-patterns have been detected that reflect the same error in the card selection phase when the robot is turned 90º to its left: the T-pattern with order number ID 3.1. (participants 1, 3 and 5 in step 3) and the T-pattern with order number ID 5.2 (participants 1 and 9, in step 5), in which participants incorrectly select a card with the command f̈orwardïnstead of ẗurn righẗ; and, (c) When the robot is turned 90º to its right, in the card selection phase, the same error as in the previous situation is detected, but with contrary orientation. Specifically, the T-pattern with order number 4.1 (participants 4, 7, 8, 9, 10 and 11, in step 4) in which the participants incorrectly select a card with the command f̈orwardïnstead of "left turn."

Secondly, limitations have been found in the assimilation of an incipient computational language, based on the detected T-patterns that reflect errors in the choice of cards related to the ẗurn c̈ommand. The turn command -to the left or to the right-supposes the execution of the instruction without square displacement. To move from one box to another requires the command f̈orward.̈ T-patterns have been detected that show the difficulty of the 5-year-old child to bear in mind this premise: (a) the T-pattern with order number 3.2, shows how participants 8 and 10, in step 3, they omit the f̈orwardc̈ommand between the left turn and the proposed right turn; (b) the T-pattern with order number 5.1., reflects how participants 4 and 7, in step 5, do not enter the f̈orwardc̈ommand before the turn; (c) the T-pattern with order number 5.2., which has already been presented in the section on difficulties derived from the child's spatial orientation capacity, shows how participants 1 and 9, in step 5, select only five of the seven steps that the correct sequence must contain; in all cases the omission of the command f̈orwardäfter making a turn.

Sample of the limitations of the child's sequencing capacity (Elkin et al., 2014), are the errors related to the number of cards used in solving the sequence problem and that are not affected by the presence of the command ẗurn.̈ In the motor resolution problem (step 1), the T-pattern with order number 1.2, reflects how participants 3, 8 and 11 select, on their first attempt, one more card in the sequence -the last one, with the command f̈orward-̈. The same sequencing error has been detected in step 2. Specifically, the T-pattern with order number 2.1, shows how participants 8 and 11 select, on their first attempt, one more card in the sequence -the last one, with the command f̈orward-̈. The T-pattern with order number 6.1 shows how participants 3 and 9, having correctly completed the first six displacements of step 6, make mistakes in the last part of the sequence in which only f̈orwardc̈ommands should be activated.

The decomposition of the problems into simpler parts and the elaboration of resolution algorithms have allowed students to carry out a self-evaluation of the process through computational thinking (Wing, 2006), as shown by the T-patterns that incorporate a self-evaluation of the procedure. In step 1, the only step that has a motor phase, the T-patterns with order number 1.1 (participants 3 and 8) and order number 1.2 (participants 3, 8 and 11) show how the students discovers for himself, in the motor phase, the specific error in the sequence of selected cards and he self-corrects it satisfactorily, and without the intervention of the teacher, in the second attempt of the card selection phase. On the other hand, from the feedback provided by the path followed by the robot, the T-pattern with order number 2.1 shows an auto-correction -in a second attempt and removing the card corresponding to the wrong command- from participants 8 and 11 in step 2, after discovering the programming error as a result of the robot's travel.

The use of an educational robot has favored the understanding and analysis of the challenges posed, but the interaction of the teacher with the participants has turned out to be a very relevant aspect to encourage the reasoning of students (Bers et al., 2019; Alonso-Tapia & Nieto, 2019) based on the mistakes made -at the end of the attempt-, promoting self-correction by the participants. An example is the T-pattern with order number 2.1. (*step* 2) which reflects how the teacher promotes reasoning in participants 8 and 11 at the beginning of the second attempt of the card selection phase, which will end with the satisfaction of solving the challenge by the participants.

The observation system designed has allowed characterizing the difficulties in the assimilation of an incipient computational language of Early Childhood Education students. The results obtained will allow the optimization of the didactic sequences that constitute the activities with ground robots of programmed directionality, favoring the improvement of educational programs that stimulate the development of computational thinking in schools (Bers et al., 2019; Lee et al., 2011). In a later work, the aim is to extend the study developed to children from all the Early Childhood Education courses in order to deepen the development of computational thinking in Early Childhood Education and the difficulties involved.

Acknowledgments

The authors gratefully acknowledge the support of a Spanish government subproject *Integration ways between qualitative and quantitative data, multiple case development, and synthesis review as main axis for an innovative future in physical activity and sports research* [PGC2018-098742-B-C31] (2019–2021) (Ministerio de Ciencia, Innovación y Universidades/Agencia Estatal de Investigación/Fondo Europeo de Desarrollo Regional), that is part of the coordinated project *New approach of research in physical activity and sport from mixed methods perspective* (NARPAS_MM) [SPGC201800X098742CV0]. In addition, authors thanks the support of the Generalitat de Catalunya Research Group, *GRUP DE RECERCA I INNOVACIÓ EN DISSENYS (GRID). Tecnología i aplicació multimedia i digital als dissenys observacionals* [Grant number 2017 SGR 1405].

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