Article

Computational Thinking and Down Syndrome: An Exploratory Study Using the KIBO Robot [†]

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Abstract: Computational thinking and coding are key competencies in the 21st century. People with Down syndrome need to be part of this new literacy. For this reason, in this work, we present an exploratory study carried out with students with Down syndrome with cognitive ages of 3–6 years old using a tangible robot We applied the observational method during the sessions to analyze the participants' emotional states, engagement, and comprehension of the programming sequences. Results show that people with cognitive disabilities can acquire basic programming and computational skills using tangible robots such as KIBO.

Keywords: computational thinking; coding; programming; robotics; Down syndrome

1. Introduction

Programming is seen as a key skill in the 21st century and a new literacy [1–4]. In the same way that, in past centuries, it was necessary for citizens to learn to write, in the 21st century it is necessary that citizens learn to code or program to be digital producers of information, not just digital consumers of it [5]. In this regard, the European Digital Agenda considers that "coding is today's literacy and helps to practice 21st century skills, such as problem solving, teamwork and analytical thinking" [6]. In addition, the European Digital Agenda deems the acquisition of digital competences essential to sustain economic development and competitiveness [6].

As a result, the term "computational thinking" has recently gained interest in the academic world, although its beginnings date back to the 1960's, with S. Papert and his constructionist approach to the LOGO programming language, which allowed students to create their own problem solving processes [7,8]. Janet Wing [9] recuperated the concept of computational thinking and defined it as a mixture between different forms of thought for solving problems (engineering, mathematical, scientific) through formal abstraction and a real and everyday world approach. Thus, Wing defined computational thinking as "solving problems, designing systems, and understanding human behavior

using the fundamental concepts of computing" [9]. The interest in this term continues to grow, as does the number of initiatives to promote its effective introduction in schools [10–14].

Coding, programming, and computational thinking constitute a way for people to express and share their ideas [15]. In this sense, these skills can be integrated into almost any class activity, with or without technology, as a new literacy and a new way of thinking, integrated with other parts of the curriculum.

Furthermore, educational robotics is a didactic approach that can be integrated into different educational environments [16]. This integration can be done through the use of programmable robotic devices and the application of project-based learning methodologies. The acquisition knowledge process can be improved through research and experimentation [17]. Robots can be used as physical tools for the development of cognitive skills through play, creativity, and the resolution of challenges [8]. Interaction with robots occurs physically when children manipulate the tool itself, play with it, and observe its movements [18]. Robots have appealing features and functions for children that able to maintain children's attention for a longer period of time, improving their performance, their ability to concentrate, and their cognitive flexibility, but it has also been found that a robot alone is not motivational enough [19]. The motivation for the use of the tool emerges from the activity, the problem or challenge to be solved, or from the story that the children represent using the robot [20]. For example, converting a robot into a character with a mission to fulfill or a role to embody engages children in different types of activities, offering them the opportunity to explore the possibilities of the environment [21].

If the motivation for children to use a robotic tool is born of the challenge to achieve, it is possible to take advantage of this great opportunity to create learning environments and situations with clear curricular objectives, through which children feel strongly attracted and committed, encouraging their curiosity, creativity, and active participation, and in which they have an opportunity to build their own learning, enriching the experience while gaining digital and computational skills [4]. Furthermore, robots can also be very helpful in the teaching-learning of programming and computational thinking at a young age [22].

As we mentioned above, coding, programming, and computational thinking constitute a new literacy, and it is essential to start integrating computer literacy for all citizens, including those with special needs, such as people with Down syndrome (DS) [23,24]. Just as past people with DS started to learn mathematics [25,26], nowadays it is time to start teaching them the same computational skills as the rest of 21st century society. Some of the primary skills that can be achieved by working with robotics include problem solving, reasoning, and planning. People with DS have the same learning goals as other students, the difference being that they are slower to learn and need more individualized and personalized teaching [25]. For this reason, it is necessary to adopt pedagogical practices and resources that allow us to address and develop their skills based on their individual goals and capacities [27].

According to Nadel [23], Down syndrome is caused by a genetic alteration in people who have 47 chromosomes instead of the usual 46 (trisomy on chromosome 21). Brain digenesis is responsible for intellectual disability, which influences their ability to emit and articulate words.

Every person with Down syndrome is unique, so each person with DS can exhibit different learning characteristics to varying degrees. Thus, every situation and every student is different, but there is extensive, well-documented evidence on teaching approaches that have a positive impact on learning for students with Down syndrome [28]. We thus need to consider the needs and learning styles of each person with DS [29], taking into account an overall perspective of the individual, attending to their personal, social, and family needs [30,31]. It is also necessary to determine the specific cognitive characteristics of students with DS, which according to Martos-Crespo [29] are the following:

- They process and organize information slowly, with difficulty.
- They present a deficit in short-term memory, both auditory and visual; however, they capture information better by the visual channel than by the auditory one.
- Their receptive-comprehensive capacity is clearly superior to the expressive one.

- They learn faster by watching their classmates and imitating their responses.
- They work on an activity until they achieve what they propose.
- They have problems generalizing their knowledge to other situations.
- They have difficulties with language, both in the articulation and acquisition of new vocabulary.

These characteristics have been summarized and generalized, but each person with DS can have different degrees of disabilities. Thus, it is necessary to consider each case individually and adapt the educational processes accordingly. Research shows that children and young people with DS can improve their learning and skills with appropriate teaching strategies and social environments [16]. For this reason, our research has created activities adapted to each particular student with DS.

In light of the importance of computer literacy for all citizens, including people with special needs, in this study we explore if KIBO robot engages and promotes the learning of basic programming and computational thinking skills in students with DS. The main research questions of this exploratory study are:

1. Do students with DS and cognitive levels from ages 3 to 6 engage with the KIBO robot in a 1:1 or 1:2 class, as measured by their attention span, interest, motivation, and positive emotions?
2. Can students with DS code with KIBO, as measured by their degree of understanding the sequences and programming?
3. How does KIBO affect the emotional behavior of students with DS, as measured through the emotions observed during their interactions with the robot?

2. Related Works

2.1. Computational Thinking Abilities

The definition of Computational Thinking (CT) incorporates a set of associated abilities, but there is no consensus of these abilities to date. According to the Computer Science Teachers Association and the International Society for Technology in Education, CT is a problem-solving process that involves different abilities, such as formulating problems in a way that makes it possible to use a computer and other machines to solve them; logically organizing and analyzing data; representing data through abstractions, such as models and simulations; automating solutions through algorithmic thinking (a series of discrete and ordered steps); identifying, analyzing, and implementing possible solutions in order to achieve the most effective and efficient combination of steps and resources; and generalizing and transferring this problem solving process to a wide variety of problems [32]. Google also defines a set of abilities associated with CT, such as: decomposition of a problem or task into discrete steps; recognition of patterns (regularities); generalization of such patterns and abstraction (discover the laws or principles that said patterns); and algorithmic design (develop precise instructions to solve the problem and its analogues) [33]. Grover and Pea [31] define CT as a set of skills, such as the abstraction and generalization of patterns (including models and simulations); systematic processing of information; symbolic systems and representations, including algorithmic notions (control flow diagrams), structured problem decomposition (modularization), iterative, recursive and parallel thinking, conditional logic, efficiency and performance, and deep and systematic error detection. Brennan and Resnick [34] define three dimensions of CT: (a) those that programmers use when creating programs that are applicable to other contexts, whether they involve programming or not (sequences, cycles, parallelisms, events, conditional, operators and data); (b) computational practices, those that are used when programming and that focus on how, not what, one is learning (iteration, testing and debugging, reusing and remixing, abstracting and modulating); and (c) computational perspectives, which users build on themselves, and their environment through programming (express, connect, and ask). Bers [3] proposes the "powerful ideas" of CT, such as algorithms (sequencing/order, logical organization); modularity (breaking up a larger task into smaller parts, instructions), control structures (recognizing patterns and repetition, cause and effect), representation (symbolic representation, models);

hardware/software (smart objects are not magical, objects are human engineered); design process (problem solving, perseverance, editing/revision); and debugging (identifying problems, problem solving, perseverance). These different CT abilities can be developed with tangible robotics, such as KIBO. For example, children can arrange a sequence of blocks to build a program (algorithm), use a repeat block instead to scan a large number of blocks (modularity), or recognize the begin and end blocks to build a program (control structures), among other abilities related to CT.

2.2. CT, Robotics and Cognitive Disabilities

New robotics kits have evolved to become the modern generation of learning manipulatives that help children develop a stronger understanding of mathematical concepts, such as number, size, and shape, in much the same way that traditional materials like pattern blocks, beads, and balls once did [35–37]. Unlike many digital games developed for children, building with robotics does not typically involve sitting alone in front of a screen [38]. Previous research has shown that children as young as three years old can build and program simple robotics projects [39–42]. Additionally, robotic manipulatives allow children to work on skills that are important for healthy child development, such as fine motor skills and hand-eye coordination [43], while also engaging in collaboration and teamwork. Additionally, robotics and programming allows children to exercise meta-cognitive, problem-solving, and reasoning skills [44].

Some recent studies have demonstrated the feasibility of teaching basic programming skills and uses of educational robotics as an effective learning resource [1,45]. It has been demonstrated that educational robots promote superior cognitive functions, like executive functions involved in problem solving, such as reasoning and planning, in typically developing preschool children [45]. We will mention two studies related with DS and computational thinking. Taylor et al. [46] presented a single case study to explore the feasibility of teaching basic computer programming skills to early elementary students with Down syndrome. They used evidence-based practices (i.e., explicit instruction), physical manipulatives, and a robot. Another study [45] examined the feasibility of promoting executive functions in people with DS using the Bee-Bot robot. Qualitative results on two children were presented and discussed, indicating that the robot promoted their interest, attention, and interaction with adults and peers, though executive functions were only enhanced in one child. Another related work that explores the feasibility of using KIBO with special-needs individuals was conducted by [47]. They studied the feasibility of using KIBO to improve the social interactions and emotional states of children with severe Autism spectrum disorder (ASD). Results shows that, although participants demonstrated a limited understanding of programming concepts, the KIBO robot yielded a positive impact on their social interactions.

Taking into consideration previous findings, in this study we explore the feasibility of using a robotic platform called KIBO to allow persons with DS to learn programming and computational thinking [39].

3. Materials and Methods

3.1. Overview

The pilot study was carried out in the Tenerife Down Association, Tenerife, Spain during five weeks from April to May of 2018 in the students' regular classrooms. Before the start of the pilot exploratory case study, we conducted a training session on KIBO with the professionals of the Tenerife Down Association [48]. The study was then approved by the board of the Tenerife Down Association. After that, we contacted the professionals interested in participating in the study and selected the students with them. An informed consent was then sent to the student's families. Seven participants diagnosed with DS aged between 7 and 19 years old (cognitive ages of 3 to 6 years) and two tutors participated during the sessions. The information on the curricular level of the students and their profile was provided by the tutors. The methodology selected to conduct the research was the exploratory

case study, according to each participant's specific needs and personalized attention requirements. We also wanted to understand the phenomenon to generate ideas for a further hypothesis [49]. We collected qualitative data using the observational method to assess the emotions, attitudes, and programming skills developed by the students in the sessions using different rubrics (Appendix A). We also interviewed the tutors to ascertain their views on including robots in their classroom, if they consider the inclusion of robots, coding and computational thinking to be of interest to students with Down syndrome, the integration with other learning objectives, and their perception of the participants' learning. Then, we coded and analyzed the data collected by the qualitative instruments.

Regarding the assessment of emotions in educational settings, researchers from the Human Computer Interaction area recognize the importance of the student's emotional state in the learning process [50], [51]. As the main goal, researchers want to know how a student is feeling in the classroom in order to produce significant learning [52]. González et al. [53] propose different methods and techniques to evaluate the emotional state of children, such as facial expressions, and subjective measures of sentiment through questionnaires, interviews, and self-reports, using a multidimensional categorical approach. These authors propose the following types of instruments for emotional assessment:

- Verbal: Likert scale or semantic difference to classify emotions; standard emotional profile (SEP), reaction profile, attitude towards ad scale.
- Non-verbal: PrEmo, EmoCards, SAM, LemTool o GEW.
- Facial expressions: Affdex SDK, Facial Coding, FaceAPI, FaceSense, FaceReader, FaceSDK.
- Brain signals: Emotiv-EPOC.
- Biometrics: Wearables for emotional assessment.

In this work, we selected a subjective emotional assessment instrument called EMODIANA [54]. This instrument portrays ten principal emotions: love, joy, satisfaction, surprise, nervousness, shame, sadness, and fear. The EMODIANA can measure not only the emotion, but also its intensity. In particular, we used an EMODIANA adapted for DS that allows the observer to register the different emotions of a student during a session (Figure 1) [52]. This instrument can be used directly during the session or to analyze recorded videos of a session [55]. After that, it is possible to classify the emotions into positive, negative, and neutral emotions.

3.2. Participants

The study participants were seven students (3 women and 4 men) with chronological ages between 7 and 19 years. It should be noted that the cognitive ages of the participants did not correspond to their chronological ages, meaning some of the older participants had lower cognitive levels than those of the lower chronological ages. The contents and activities involved were adapted to the particular needs of each participant and were developed by the tutors and professionals in charge of each participant's education. Table 1 describes the characteristics of each participant.
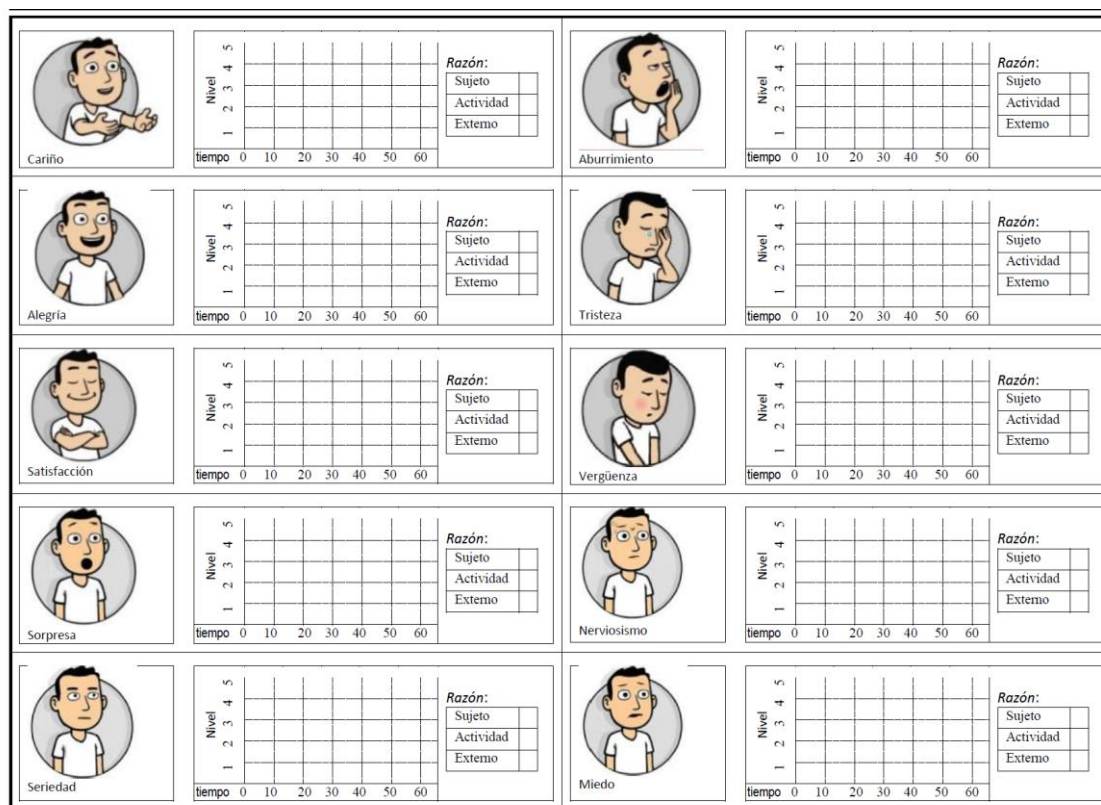
Figure 1. Observational instrument for evaluating emotions in educational contexts [55].

Table 1. Description of participants, where P: Participants; ChA: Chronological Age and CgA: Cognitive Age, and the content to be taught.

P	ChA	CgA	Sex	Content
1	10	6	M	Language integrated with programming and computational thinking.
2	7	5	F	Language integrated with programming and computational thinking.
3	11	5-6	M	Speech therapy integrated with programming and computational thinking.
4	19	3-4	M	Speech therapy integrated with programming and computational thinking *.
5	13	6	F	Mathematics integrated with programming and computational thinking.
6	15	6	F	Speech therapy session integrated with programming and computational thinking.
7	14	3-4	M	Mathematics integrated with programming and computational thinking.

* This participant on many occasions required the specialist to translate the information using sign language.

3.3. Robotic Technology

This study utilizes the KIBO robotics kit, created by the Developmental Technologies Research Group at Tufts University through funding from the National Science Foundation (NSF). KIBO is a robotics construction kit that involves hardware (the robot itself) and software (tangible programming blocks) used to make the robot move. KIBO is unique because it is explicitly designed to meet the developmental needs of young children. The kit contains easy to connect construction materials, including wheels, motors, light output, and a variety of sensors (See Figure 2).

Figure 2. KIBO robot with sensors and light output attached.

KIBO is programmed to move using interlocking wooden programming blocks (see Figure 3). These wooden blocks contain no embedded electronics or digital components. Instead, KIBO has a scanner embedded in the robot. This scanner allows users to scan the barcodes on the programming blocks and send a program to their robot instantaneously. No computer, tablet, or other form of "screen-time" is required to learn programming with KIBO. This is in keeping with the American Academy of Pediatrics' recommendation that young children have a limited amount of screen time per day [36]. KIBO's block language contains a total of 18 different individual programming blocks for children to learn, with many increasingly complex programming concepts that can be introduced, including repeat loops, conditional statements, and nesting statements.

Figure 3. Blocks for programming KIBO and a sample KIBO program. This program tells the robot to spin, shake, move backward, move forward, and turn a red light on.

In addition to these robotic and programming components, the KIBO kit also contains art platforms that can be used by children to personalize their projects with crafts materials and foster STEAM integration.

The KIBO robotic kit was chosen for this study for several reasons. First, as mentioned, KIBO is designed specifically for a target population of children aged 4–7 years old, allowing them to engage with computer science concepts in a way that is developmentally appropriate [4,39,56]. The kit, therefore, innately reduces both the complexities of manipulation and coding comprehension. In addition, to program the robot, the KIBO kit relies on wooden blocks that are easily recognized and manipulated. Further, KIBO is a tangible, screen-free robotic platform with an easy visual interface that can potentially promote face-to-face interactions with teachers and peers. Also, KIBO is different from other available robotic kits in that it does not require screen time on a separate computer. Programming is accomplished by connecting tangible wooden blocks that children assemble in a sequence to provide

a set of instructions to the KIBO robot. Each block is color-coded and labeled with an action or instruction that tells the robot what to do. After a sequence is built, starting with a "Begin" block and ending with an "End" block, children can program the robot by scanning the set of blocks in sequence using the KIBO's built-in barcode scanner. Children then simply push a button to see the robot perform the program they created. The robot has slots for up to four sensors that can be assembled and dissembled to add or subtract functionality.

3.4. Activities

We designed activities that were adapted to the participants based on their curriculum level. The contents related to computational thinking and coding were also integrated into the current subject that each participant was working on at that particular time in the course, and which the teacher considered was most relevant to the student.

In total, 23 activities were designed with different durations, from 15 to 30 min. Thus, a one-hour session was organized with 2 to 4 activities, depending on the case. Some examples of different types of activities are shown in Table 2.

The first activity common to all participants was the introduction to KIBO. The main goal of this activity was to introduce the robot, each of its elements, and how it works. In this session, the participants also learned how to program a basic sequence with KIBO (Figures 4 and 5). This session lasted 20 min.
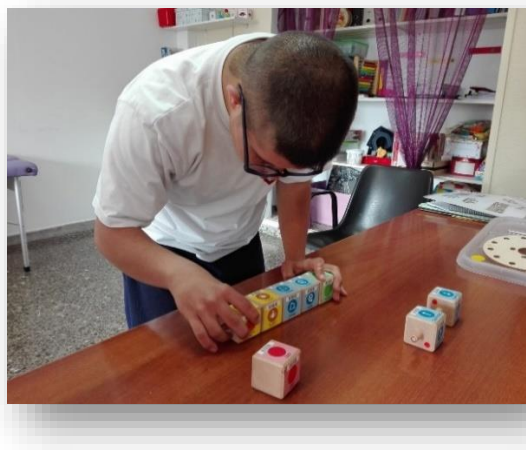

Figure 4. Student with Down syndrome creating a basic program sequence.

Figure 5. Student with DS scanning a basic sequence to move KIBO.

Table 2. Examples of different activities carried out with children.

Name	Characteristics	Description	CT Abilities
I'm a robot	Type: Introduction Robotic focus: Introduction to engineering and robotics Duration: 20' Goals: ● Learn about KIBO and each of its elements. Contents: ●Knowledge of the robot and its operation. ● Basic program sequences Materials: ● KIBO robot ● Sheet with images of robots	To introduce the topic, we asked the following questions: What is a robot? Do you know what a robot does? Have you ever seen a robot? We then showed them a sheet with different images of robots, explaining how each robot is as different as people are and, therefore, have different skills and different ways of communicating, like people do (English, Spanish, French, sign language, etc.). The sheet contains an image of KIBO and, to encourage the surprise factor, we asked some questions about it and focused our comments on it, before telling them that they will be able to meet KIBO soon. We then introduced KIBO in the session. We explained each of the parts of KIBO and the functions that correspond to them, as well as the wooden blocks, which are the language that KIBO uses. Over the course of the explanation, we implemented some simple programming sequences while interacting with the students, so that they could also program KIBO.	CT1, CT4
See how I program you!	Type: Language Robotic focus: Introduction to what a program is Duration: 20' Goals: ● Interpret visual patterns through the KIBO programming language. ● Program the partner or monitor through the cards. ● Program KIBO to execute the messages. Contents: ●Knowledge of the programming language. Materials: ● KIBO robot ● Sheet with images of the activity	We showed cards with images similar to the KIBO language (start, blue light bulb, spinner, arrows, etc.). The participants had to use them to create a programming sequence on the table, so that later the partner or monitor could interpret them. Then it would be the turn of the monitor or partner, and several sequences would be programmed. Then we used some of the sequences that we liked the most, which would be interpreted and transformed into KIBO's language (using its wooden blocks).	CT2, CT3, CT4, CT5, CT6
KIBO, move the skeleton!	Type: Music/Body knowledge Robotic focus: Introduction to sensing and sensors Duration: 30' Goals: ● Program the robot to execute the indicated movements. ● Enhance learning by discovery. Contents: ●Knowledge of the programming language. Materials: ● KIBO robot	We reviewed the parts of KIBO, compared with the five human senses and locomotion. We were then going to start programming with the wooden blocks. To do so, the participants had to decide the movements that they wanted KIBO to do, as if we were choreographing KIBO to move in response to selected music. As a group, we commented on the blocks that we needed to make the robot come alive in the appropriate way, before implementing the sequence with KIBO. We repeated several choreographies. We compared our body with KIBO's elements and movements.	CT1, CT2, CT3, CT4, CT5, CT6

Table 2. *Cont.*

Name	Characteristics	Description	CT Abilities
Follow me!	Type: Attention and auditory memory. Robotic focus: Sensing and introduction to repeats Duration: 15' Goals: ● Repetition of auditory sequences ● Visual and auditory identification of KIBO wood blocks ● Program the sequence that has been repeated through KIBO. Contents: ● Identify different blocks in the KIBO programming language. Materials: ● KIBO robot	We reviewed what a sensor is and compared it with the human senses. We talked about the meaning of repeat. We listened to and repeated a KIBO language sequence: "Turn, one step forward and two steps back", and then identified it with the wooden blocks and layed out the sequence. To finish, we programed KIBO to interpret our sequence. We programmed different sequences, making them longer, simpler or more complex, to match the student's characteristics.	CT1, CT2, CT3, CT4, CT5, CT6
He eats numbers	Type: Mathematics Robotic focus: Repeat with numbers Duration: 30' Goals: ● Continue the series of numbers indicated. ● Program KIBO to reach each of the numbers we need. Contents: ●Knowledge of the programming language. ● Sequencing, series Materials: ● KIBO robot ● Different numbers in folio size.	We placed different numbers on a table, forming an incomplete series, for example: 2, X, 6, X, 10 (indicating to the participant that the series was obtained by adding 2 to each previous number). Once the incomplete series was laid out, we distributed several numbers in the space, which matched (or did not match) those needed to complete our series. The participant had to program KIBO to reach each number it needed to select to complete the series. We programmed KIBO to travel around different numbers using repeats.	CT2, CT3, CT4, CT5, CT6

CT1: hardware/software (smart objects are not magical, objects are human engineered); CT2: algorithms (sequencing/order, logical organization); CT3: modularity (breaking up larger task into smaller parts, instructions), control structures (recognizing patterns and repetition, cause and effect); CT4: representation (symbolic representation, models); CT5: design process (problem solving, perseverance, editing/revision); CT6: debugging (identifying problems, problem solving, perseverance).

Other KIBO activities involved curricula, such as mathematics (numbers and basic operations) or language (lexical/semantic/phrases), and other functional contents or cognitive/speech therapy, like emotional knowledge, social relations, timing, attention and auditory memory, and knowledge of the body.

3.5. Sessions

The sessions included an initial familiarization and diagnosis session, where the researcher observed what content they were working on and how they learn it without KIBO. This first session was necessary to observe the curricular level that was being worked on in the classroom, as well as the response of each student in the group of students, their different capacities, and their attitudes. We also received different indications on the level of each participant and recommendations, such as the type of writing they are currently able to read, the operations and ways in which they could be done, and other specifics to consider in order to design activities with KIBO successfully.

In the second session, we introduced the KIBO robot and its programing in the classroom to all of the participants. To do so, we implemented several presentation activities that we had previously prepared. These activities considered KIBO's multiple functions, its programming language through wooden blocks, and how it communicates. Over the course of these sessions, we compiled a progress record of the different emotions of the students, as well as a corresponding evaluation of their programming and computational thinking skills.

By considering the response of each student during the previous sessions, we designed activities that aimed to arouse in each one of them an interest and enthusiasm in programming KIBO. To do this, as mentioned earlier, we relied on activities suited to the curricular level of each as a guide. Thus, in the third session, activities related to their curriculum and/or therapy were carried out with KIBO. We, therefore, worked with both content types, which related to computational thinking and programming and corresponded to the adapted curriculum. The sessions had different degrees of success for each participant. We analyzed the results later, but in general this third session was completed without difficulties and with great acceptance by the participants. We used different evaluation instruments to assess the session.

Finally, we conducted interviews with the tutors to determine their own assessments of their students' learning, as well as other aspects of the intervention.

3.6. Data Collection and Analysis

A KIBO expert on the research team led each session, explaining each activity and the schedule of events. The expert collaborated with the regular teachers to conduct each day's sessions. At the end of each session, the research team had a debriefing to review what had happened.

We collected information using the following methods: (1) video recordings of all the sessions; (2) observational checklists on emotions and computational thinking skills; (3) assessment rubrics and notes that were taken during and after the sessions; and (4) interviews with teachers at the end of intervention. For a more detailed analysis, the video data was coded and analyzed with ratings by an independent observer. Appendix A presents the assessment rubrics used in this study.

In the first intervention session, we observed the contact with the robot, the motivation, involvement and disposition towards KIBO and the proposed activities. An assessment rubric was provided to indicate if the participants complied with the items proposed.

In the second intervention session, we assessed each participant's progress through observation, using a record similar to that employed in the previous sessions. In addition, we evaluated the emotions exhibited over the course of the sessions.

At the end of the intervention, we conducted an open interview with two of the professionals responsible for teaching the participants on different aspects of the pilot study. In their entirety, the records generated reliable and valid information for issuing value judgments that support the evaluation, and allowed us to determine the results of implementing the activities, as well as the

effectiveness of introducing tangible robotics (in this case, KIBO) to the various participants. They also highlighted the drawbacks encountered in the robot application process.

4. Results

In this section, we present the main results of this pilot study and answer the research questions. Regarding the research question of this pilot study, "Do students with DS engage with the KIBO robot? (degree of motivation)", the results showed a positive engagement impact. The interest in the activities was high (1) in 3 participants and medium in the other 3 (0.5). The programming motivation was medium (0,5) in 4 participants and high in one (1), and every participant interacted with KIBO satisfactorily. On the question "Can DS students code with KIBO? (degree of comprehension of the sequences and programming)", we observed that except for two students, five understood KIBO's blocks and elements and were able to program basic sequences to achieve the goals proposed in the activities. Four students were able to program KIBO without help. On the third research question, "How does KIBO affect the emotional behavior of students with DS? (observed interactions and emotions)", we observed high positive emotions during the intervention with KIBO in six students (1), medium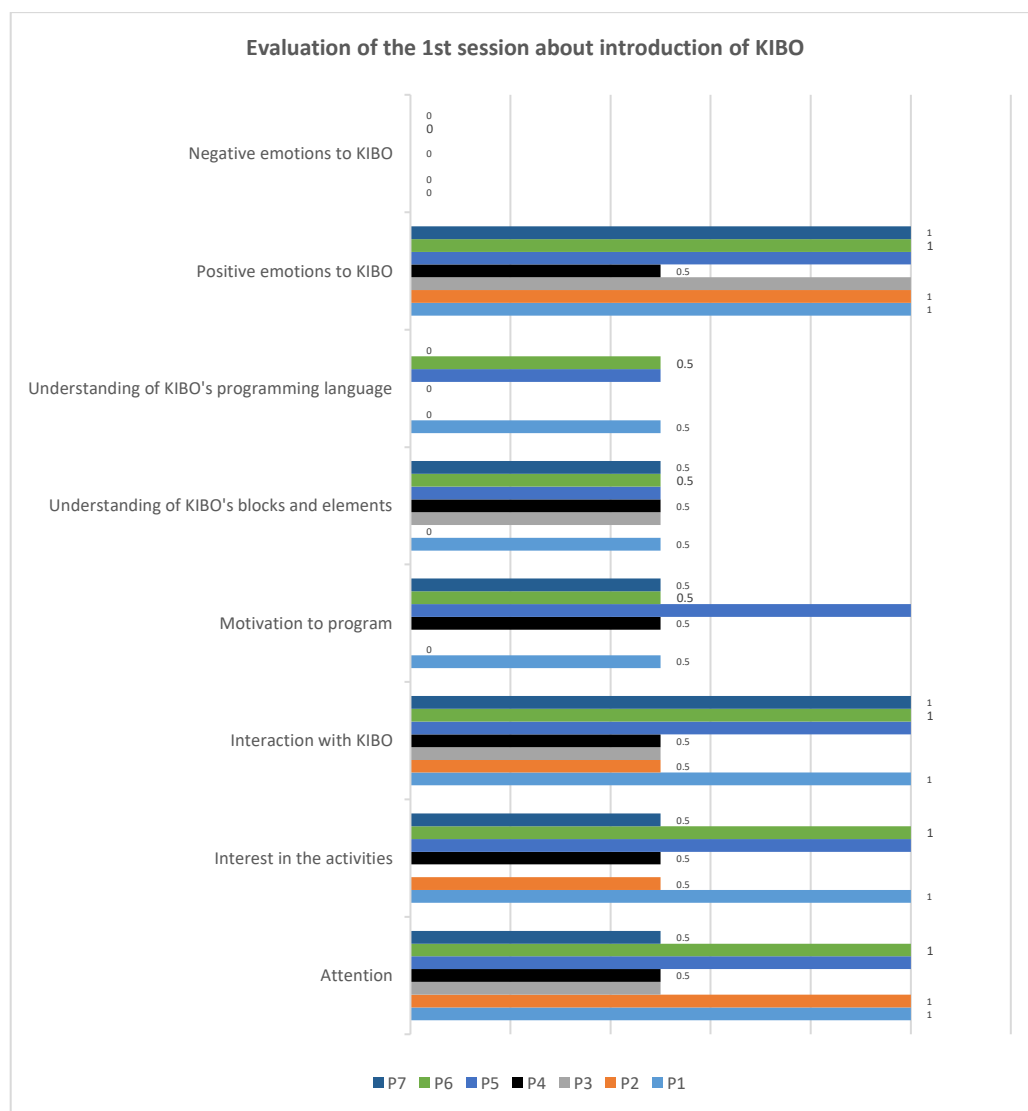 in one (0.5), and no negative emotions. Figures 6 and 7 show the results of the behaviors observed during the two intervention sessions where the students worked on programming concepts.

Figure 6. Results of the behaviors observed in the first, introductory session to the KIBO robot.
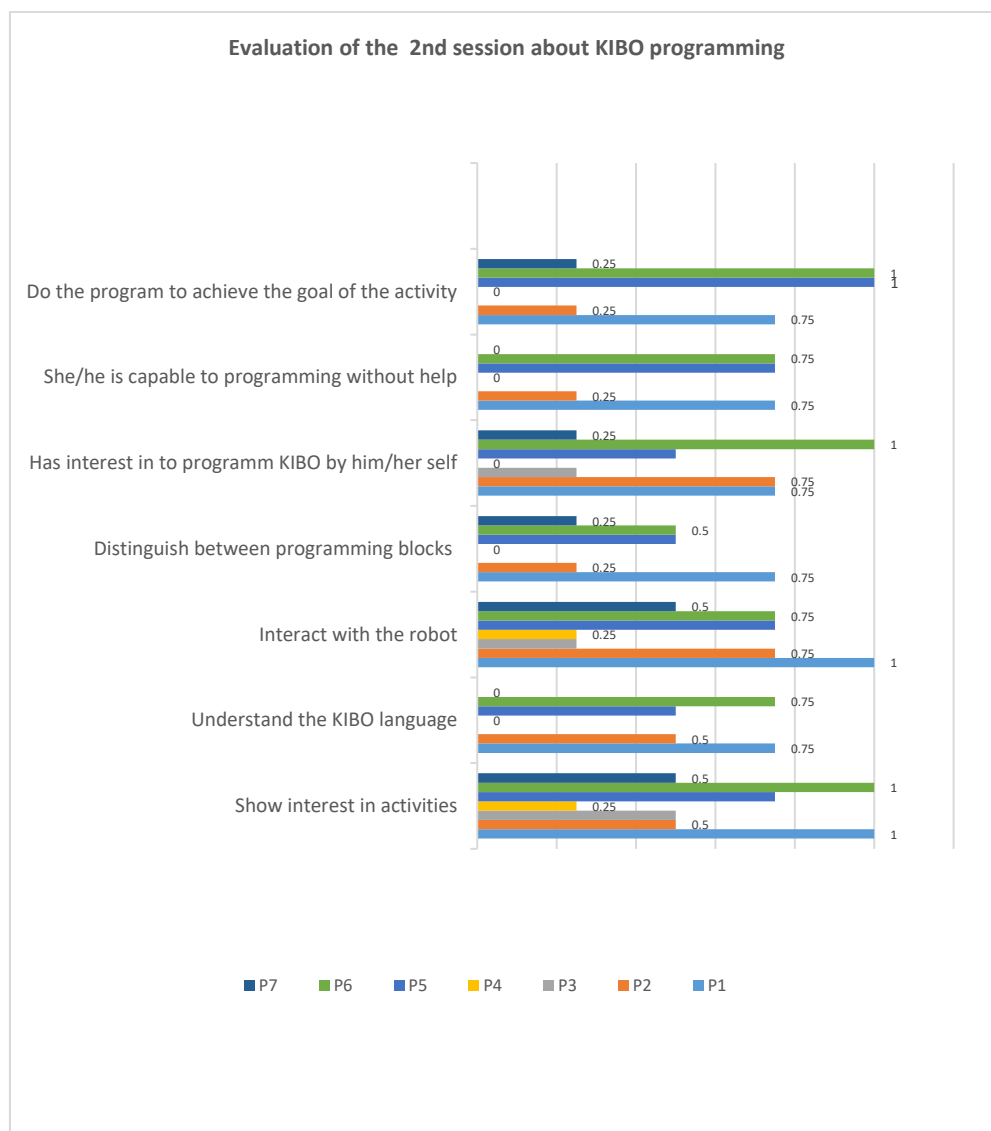
Figure 7. Results of the behaviors observed in the second session, on programming KIBO.

Concerning the CT abilities, Table 3 summarizes the main findings for each participant in each session.

Table 3. Main findings on CT abilities per participant.

Participant	CT Abilities Observed
1	**Session 1. Diagnosis and familiarization.** Student initiated in reading and writing and logical-mathematical thinking. Vague knowledge of robots from cartoons and movies. Correctly processed the information, but had problems organizing it logically. Was sometimes able to distinguish between elements or objects with the same property. **Session 2. Introduction to robotics and programming.** Was attentive to the presentation of the robot and responded correctly to questions about the KIBO robot by asking questions about its elements and operation. After a simple explanation of how the KIBO scanner processes the codes, was consistently able to do it by himself, managing to control the distance to the scanner, which sometimes complicated the reading. Was not able to distinguish at all between the different programming blocks, confusing them at times, which resulted in incomplete knowledge of the robot's programming language. **Session 3. Programming and curriculum.** Remembered the operation of the robot and how to program it. We worked on activities related to language in which the participant had to select a word with an action and then program the robot to perform that action. In addition to the action requested, the participant added other actions that amused him (for example, turning on the light bulb). A positive evolution was observed in terms of problem solving and programming.
2	**Session 1. Diagnosis and familiarization.** Was easily distracted. Only rarely did she organize and analyze the information received. Had problems distinguishing objects and/or elements from among properties. Was introduced to reading–writing and mathematical/logical thinking. **Session 2. Introduction to robotics and programming**. Had not heard of robots before. Did not make any comments or ask questions about how KIBO works. She was very enthusiastic about combining the different blocks, trying to incorporate as many as possible, with no prior instruction or intention. The participant did not want to receive help as to how to read the blocks with the scanner on the robot, indicating that she wanted to do it herself. She was also not receptive to asking questions related to the order of the actions she wanted KIBO to perform. Showed no interest in programming the robot to carry out an activity in a specific way. Not quite able to distinguish between the different programming blocks. Showed no effort to understand the KIBO language. **Session 3. Programming and curriculum**. Remembered KIBO and showed great enthusiasm about working with it again, although she had some problems remembering all of KIBO's parts and how they worked. In programming, she focused on joining the blocks in no logical order. With the help of the teacher in the activity of reading the sentences, she was able to relate the image with the action to be performed. In programming, added unnecessary blocks that distorted the path of the robot.
3	**Session 1. Diagnosis and familiarization.** Little desire to participate. The participant did not have verbal fluency and had problems expressing needs or thoughts. The speech therapist used sign language to reinforce communication with him. Based on the indications provided by the speech therapist, we can state that he is being introduced to reading–writing and to mathematical/logical thought. **Session 2. Introduction to robotics and programming.** Showed considerable interest in the robot and its operation. The speech therapist's support was required to communicate with the participant. Closed questions were asked about the actions he wanted KIBO to execute and the student had to program the robot to do them. The light on KIBO's scanner distracted him, which made it difficult for him to handle the wooden programming blocks. With help, the student was able to perform basic programming sequences. There was a positive evolution in his knowledge of the robot, but he did not exhibit an interest in the activities proposed. He was not interested in programming the robot to perform a given action and did not try to understand the programming language. **Session 3. Programming and curriculum.** The participant remembered the name of the robot and on the days when we were not present, he asked his teacher about KIBO. The student did not show any interest in performing the activities. Since he was practicing blowing as part of his speech therapy, the activity was adapted by placing a series of pens on the platform with KIBO that the student had to try to knock down by blowing as KIBO turned. He would later count the pens that had fallen on the table. To do this, he had to program the robot to turn around five times. With help, the student was able to program KIBO to carry out the activity.

Table 3. *Cont.*

Participant	CT Abilities Observed
4	**Session 1. Diagnosis and familiarization.** The student was easily distracted, and did not engage in mathematical logical thinking or respond favorably to literacy. **Session 2. Introduction to robotics and programming.** The student was very attentive to the explanation of the robot and its operation and surprised by how he could communicate what he wanted the robot to do through the wooden blocks. Despite his interest, he failed to distinguish between the different programming blocks and did not fully understand KIBO's language. **Session 3. Programming and curriculum.** The student remembered very little of what had been worked on in the previous session; therefore, all of the programming elements and methods had to be reviewed. The activity included the employment of a handicraft (rubber hand) that was used in the KIBO platform and social actions, such as hand greetings and movements of the robot. The student had difficulties carrying out the programming sequences autonomously.
5	**Session 1. Diagnosis and familiarization.** The student was very attentive, curious, and able to self-correct. The student organized the information she received and analyzed it logically. She was also able to distinguish between objects of a property and responded favorably to the process of reading, writing, and logical mathematical thinking, typical of her cognitive age. She had no knowledge of what a robot is. **Session 2. Introduction to robotics and programming.** The student was very attentive and anticipated the elements and operation of KIBO through questions. The activity consisted of performing different choreographies to make KIBO dance. The participant mastered the placement of the blocks from the time it was explained to her and she enjoyed the proposed activities, demanding new variants. She was able to interact correctly with the robot and distinguish programming blocks. **Session 3. Programming and curriculum.** The student remembered KIBO and its operation. She programmed different sequences related to mathematics (time, series of numbers) and a game with dice and KIBO movements. She was able to program KIBO autonomously and satisfied the objectives of the activity.
6	**Session 1. Diagnosis and familiarization.** She was shy and worried excessively about failing. She organized the information received and analyzed it logically. She too was capable of distinguishing objects between properties and was being initiated in the process of reading and writing and mathematical logical thinking. Of note is the fact that she read sentences with the support of pictograms. **Session 2. Introduction to robotics and programming.** She was attentive to the explanation and performed the activity of creating a basic programming sequence successfully. She was autonomous and offered help to her partner programming KIBO. She exhibited some problems distinguishing between the different programming blocks. **Session 3. Programming and curriculum.** She remembered KIBO and how it worked. We worked on her auditory attention and memory by dictating the programming sequences that had to be built with the wooden blocks. As the complexity of the sequences was increased, the participant carried out the activities in an exemplary way, accurately creating the sequences. The next activity was related to reading, and the participant had to read a set of sentences and associate them with KIBO pictograms and actions. In this second activity, the participant had problems reading sentences, but not programming KIBO, which she did correctly.
7	**Session 1. Diagnosis and familiarization.** At first, the participant was timid, but then he gained proficiency. The student was initiated in literacy, supported by pictograms, and mathematical logical thinking, but exhibited problems recognizing objects between properties. He knew what a robot was from seeing them in movies. **Session 2. Introduction to robotics and programming.** The student was very participative, interested in the different functions the robot had, and interacting during the explanation. In the activity, he had to read and interpret the sequence to be programmed with his own body and then program KIBO. He had some problems programming KIBO by himself. He was not always interested in programming the robot to perform a specific action and did not try to understand its language; therefore, he could not distinguish between the different programming blocks. **Session 3. Programming and curriculum**. The attention and auditory memory activity was carried out, in which simple sequences to be programmed were dictated. The student did not exhibit difficulties with the programming of simple sequences. He was able to read the barcodes on the blocks autonomously, but he needed help creating the sequences.

5. Conclusions

The results of this study show that KIBO engages and promotes the learning of basic programming and computational thinking skills in students with DS. However, some drawbacks were identified with KIBO, for example in the assembly of the wheel and motors, or in the scanning of the bar codes, since the children placed the blocks too close to the scanner. Sometimes the children did not wait for the beep or LED to confirm that the code had been read before continuing with the sequence. Regarding the exercises, the students sometimes simply put the blocks together with no logical sequence.

To address the different research goals, we can affirm that the KIBO robot sparked very positive emotions in DS students, and kept them motivated over the course of the sessions. All DS students responded favorably to working with KIBO, and in some cases showed progress in their knowledge of the robot and its programming, evolving positively between one session and the next.

Regarding the group of individuals with DS involved in our research, we must note that they present characteristics, skills, and aptitudes that are favorable to working with robots and programming. After our analysis of each of the seven participants, we can affirm that six of them have had very good results working on the logical–mathematical thinking skills developed. For this reason, we believe that they are able to acquire computational thinking in the same way that they acquire mathematical thinking. Some participants needed more time than their peers to acquire the same skills. In general, the process to consolidate learning in students with DS takes longer than in individuals without this condition, as they learn more slowly and differently than persons without disabilities. In the intervention sessions conducted with DS students, we incorporated different educational activities, like the KIBO robot. We introduced its elements and language programming and other activities related to other content, such as mathematics, language, emotional and social skills, etc. Through these activities, DS students were initiated in computational thinking.

As limitations of this study, we note the short period of time used to develop the pilot and the number of participants involved. Another limitation of this exploratory study is the probable bias in the subjective measurements, mainly in the observation procedures and in the interview. Therefore, we plan to extend the study in the next academic year by involving more students and tutors. We are also planning other activities on computational thinking without robots, with robots, and with tablets.

We believe that computational thinking should be initiated at an early age, together with reading, writing, and mathematical knowledge. It is necessary to start working on computer literacy from a young age in ordinary classroom settings, focusing on inclusion and on working with different types of disabilities [47]. Moreover, the teachers indicated that tangible robotics would be useful as educational tools for their students and as motivational tools. However, computational thinking needs a specific space and recognition in the curriculum and should not be considered as merely complementary.

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Appendix A —Rubrics

Table A1. Initial Assessment.

	Did she/he know about robots previously?			Does she/he organize the information received?			Does she/he analyze the information received logically?			Is he/she able to distinguish objects between properties?			Does he/she respond favorably to literacy?			Does he/she respond favorably to logical-mathematical thinking?		
	S	A	N	S	A	N	S	A	N	S	A	N	S	A	N	S	A	N
Participant 1																		
Participant 2																		
Participant 3																		
Participant 4																		
Participant 5																		
Participant 6																		
Participant 7																		

A: Always, S: Sometimes; N: Never.

Table A2. 1st Intervention Session.

	A	S	N
Pays attention when the robot is presented			
Shows an interest in the activities presented			
Interacts with the robot			
Shows an interest in programming the robot to achieve a specific goal			
Identifies KIBO's different programming blocks			
Tries to understand KIBO's programming language			
KIBO causes joy			
KIBO causes rejection			

A: Always, S: Sometimes; N: Never.

Table A3. 2nd Intervention Session.

	1	2	3	4	5
Shows an interest in the activities planned					
Understands KIBO's programming language					
Interacts with the robot					
Identifies KIBO's different programming blocks					
Shows an interest in programming the robot to achieve a specific goal					
Is capable of programming without help					
Does the programming intentionally to achieve the objective of each activity					

1 = Strongly disagree; 5 = Strongly agree.

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