Integrating Programmable Robots to Foster Computational Thinking in Early Childhood Classrooms

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Abstract

Computational thinking and educational robotics are becoming key competencies for creating competent digital citizens in today's world. The development of these skills has been gradually implemented in Primary and Secondary Education, but there is still a long way to go, especially in their use in Early Childhood Education. The use of these technologies from an early age has shown to have positive effects on students' education. This paper presents an intervention among 3-year-old students using the Bee-Bot robot. The study includes both unplugged activities and activities with the robot to develop computational thinking skills. The results show an improvement in the acquisition of these concepts with meaningful learning after conducting the robotics sessions. Additionally, the obtained results are analysed and options for their improvement are discussed. The difficulties and limitations of this study are also addressed.

Keywords
Computational thinking, educational robotics, Bee-bot, Early Childhood Education

1. Introduction

The ongoing rise of digital and technological innovation is driving societal change and demanding adaptations in education. Computational thinking (CT) involves problem-solving, designing and creating systems, and understanding human behaviour through fundamental computer science concepts [1]. The relevance of CT and digital competence is undeniable today. Introducing this skill and problem-solving approach from an early age can enhance children's competencies in areas such as logic, creativity, deductive reasoning, and logical thinking.

Several studies related to the use of programmable robots indicate positive changes in students participating in programs involving programming and CT [2] [3] [4]. Furthermore, the use of colourful robots with playful shapes increases student motivation and sparks curiosity. In Spain, specifically, national legislation incorporates CT into the educational curriculum for all K-12 educational stages including Pre-school [5].

2. Educational Experience

The goal was to foster the development of CT in early childhood education classroom using Bee-Bot robots. Three activities were carried out progressively, starting with unplugged activities

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and culminating in the main activity with the robot. To address the need for a comprehensive evaluation, we integrated qualitative insights alongside quantitative assessments. The Beginners Computational Thinking test (BCTt) [6], a recognized CT assessment instrument, was administered to students in its shortened version adapted for this age group [7], which comprises 21 questions covering basic computational concepts, used as both a pre-test and post-test instrument to quantify leaning outcomes.

Participants

The participants were children between 3 and 4 years old at a public school in an urban area in Catalonia. The activities took place in a single classroom consisting of 21 students, 4 of whom had been diagnosed with special educational needs. These children included two with Autism Spectrum Disorder (ASD), one with developmental delay, and one with a language and personality disorder. This research was approved by the Research Ethics Committee of Universidad Rey Juan Carlos (N. 291120234412023).

Activities

1. *Activity 1: What is a Robot?* The initial activity aimed to assess students' knowledge about robots and introduce their uses in daily life. Students discussed what robots are, their purposes, and differentiated robots from other objects using photos. The activity was conducted in two sessions: the first to introduce the topic and assess knowledge and the second for classification using board games.


**Figure 1:** Example of the board game used

2. *Activity 2: I Am a Robot.* The second activity took place during the psychomotor hour. A 6x6 grid was marked on the floor with adhesive tape, and students were grouped into small teams. They acted as robots, following these rules: i) **Movement**: To move from one square to another, students must jump; ii) **Turning**: To turn, students must first stop, turn in place, and then move towards the next square. Turning does not imply moving forward, so they need a separate turn card and a move forward card; iii) **Turn Restrictions**: Students cannot turn unless they have a turn card indicating it; and iv) **Instructions**: Students must follow the given instructions.

Each team received visual instruction cards and aimed to navigate towards rewards placed on the grid. Their challenge was to lay out direction cards to chart a path (each card representing movement by one square). Each team planned the route, placing visual instruction cards on the grid. Then, one student acted as the robot, following the arrows to check its accuracy. Any mistakes required them to start over.

To raise the challenge level, forbidden cards were placed on the board. These cards acted as obstacles that students had to avoid reaching the goal, so the activity became more challenging, requiring students to use different directions such as moving backward or turning more frequently.
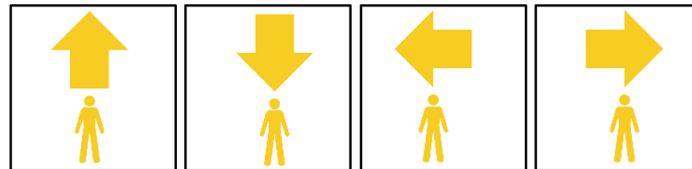
Figure 2: Directional cards
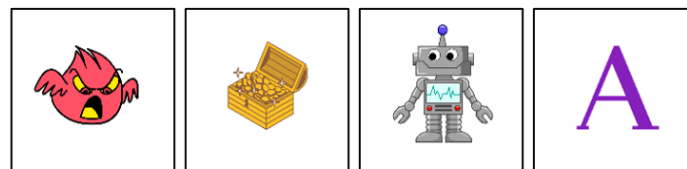
Figure 3: Rewards placed on the grid

3. *Activity 3: Bee-bot.* In this activity, students engaged with the Bee-bot robot. Initially, they learnt about the robot's functionalities, which include directional movements (forward, backward, right, left), a 90-degree turn function, a GO button to initiate movement, a pause and a reset button. They had an introductory session to explore and familiarize themselves with the robot's operations.

Next, students used a 6x6 grid on the floor with movable alphabet panels (see Figure 1). The goal was to program the Bee-bot to navigate towards the initial letter of each student's name. Initially, the paths were straightforward to help students grasp the basics of programming. As they gained proficiency, challenges were introduced, such as starting from different grid positions, or avoiding forbidden squares. Throughout the activity, students used visual instruction cards, to help them visualize and correct any errors.

Figure 4: Letter boards

3. Discussion

Participants, who were students unfamiliar with CT and educational robots, enthusiastically engaged in unplugged activities and using the Bee-bot robot. They initially showed curiosity, increasing motivation, and desire for continued engagement. During unplugged activities, especially those where they acted as robots, they demonstrated comfort and significant improvement in understanding right and left directions. Conducting activities in the psychomotor classroom contributed positively to their learning environment.

The study employed a progressive approach in introducing CT concepts through the use of the Bee-Bot robot. Initially, participants faced challenges with the robot's interface, such as recalling commands and understanding directional inputs. However, through iterative sessions and incremental learning activities, students demonstrated noticeable improvements in their ability to program the Bee-Bot effectively. Visual aids and clear instructions were gradually introduced to enhance understanding, which led to increased engagement and competency.

The administration of the BCTt [6] as both a pre-test and post-test instrument provided valuable insights into the participants' CT development over time. Despite initial difficulties, statistical analysis revealed significant learning gains among the participants (Wilcoxon test, p-value = 0.00086). This improvement underscores the effectiveness of the progressive approach in fostering CT skills, particularly in memory, strategy development, and laterality skills.

Furthermore, the use of the Bee-bot robot also presented some challenges with these participants, which are as follows:

- Display of instructions: The robot does not have a screen or panel to show the commands that have been given. Participants found it difficult to remember which button they had pressed and which direction the robot was heading. An attempt was made to solve this with panels, but the students had trouble understanding them. As a result, they chose to give directions one at a time so they could see where the robot was going.
- Clear button: Most students did not realize they needed to press the clear button before starting over. This caused the robot to move in many directions, but the students did not connect this with the previous movements.
- Arrows: The robot uses arrows on its buttons to indicate direction. Due to the complexity of understanding left and right for younger students, some had difficulty associating the buttons with the direction indicated by the arrow.

4. Conclusions

This study explores the implementation of the Bee-Bot robot with students aged 3 to 4 in Early Childhood Education to foster computational thinking (CT). By employing a progressive approach, which gradually introduced and scaffolded CT concepts through interactive activities, significant advancements in CT skills were observed. The iterative nature of the intervention not only enhanced participants' understanding of the Bee-Bot's functionalities but also facilitated the development of critical skills such as sequencing, problem-solving, and logical thinking.

The use of Bee-Bot in the preschool classroom proves to be an effective methodology for introducing CT concepts in a playful and accessible manner. The robot's tangible and interactive nature helps children grasp abstract concepts by transforming them into concrete, manipulable experiences. Children not only learn to program sequences of movements but also develop social and collaborative skills by working together to solve challenges and design paths for the Bee-Bot. Implementing the progressive approach also addresses the limitations inherent to the

preoperational stage of development at this age, children demonstrated improved understanding and application of spatial concepts such as directionality (left and right). Through games and challenges, children learn to break down complex problems into simpler, manageable actions. They also engage in pattern recognition, fostering more logical and reasoned thinking. Empirical evidence gathered during the study shows that they consistently exhibited progress in their ability to sequence commands, anticipate outcomes, and adapt strategies based on feedback from their interactions with the robot.

In conclusion, the progressive approach implemented in this study has proven effective in enhancing children's understanding of CT and their proficiency in using educational technologies like the Bee-Bot. Future research could further explore the long-term impact of such interventions and incorporate mixed methods designs to provide a comprehensive understanding of its educational benefits.

Acknowledgements

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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