# Cthink.It. A Board-game for Computational Thinking in Early Years

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**Abstract:** Computational Thinking (CT) refers to a specific set of mental skills used to formulate solutions to problems by converting given inputs to produce appropriate outputs while following detailed algorithms to perform this process. Essentially, CT is broadly defined as a combination of thinking processes which include abstraction, algorithm design, decomposition, pattern recognition and data representation.

Board-games can be used in the educational process as a learning tool while creating an attractive and authentic learning environment, providing an educational approach which is transdisciplinary, developing and utilizing multiple skills. Using board-games in Early Childhood Education (ECE) cultivates students' social skills, 21st century skills and cognitive skills, while helping them to increase their motivation and achieve the objectives of the curriculum framework.

In this paper, the aforementioned areas are combined through the presentation of a board-game that was designed within the CThink.it Erasmus+ project (2022-1-MT01-KA220-SCH-000086903) for cultivating CT competency in the early years. The backstory is a toy, lost in a museum and through a series of activities, it is to be returned to the child-owner. Prior to designing the game, a systematic literature review was conducted so as to provide foundation for the game itself and a set of associated lesson plans.

The produced materials were pilot tested in schools. The paper aims to provide preliminary data for the game evaluation, focusing on the issues of playability, age appropriateness, connection to curricula and the teachers' perspective on the usability of the game as teaching resource for ECE. For that, the research methodology will be presented, along with preliminary findings.

**Keywords:** Computational Thinking, Board Games, Early Years, Cards

## 1. Introduction

Computational Thinking (CT) refers to a set of mental skills, related to problem solving. According to Denning (2009), such skills are used to convert provided inputs for producing appropriate outputs through designing and following detailed algorithms for realizing this process, thus formulating solutions to the initial problematic state. Wing (2006) described it as a combination of thinking processes which include abstraction, algorithm design, decomposition, pattern recognition and data representation.

With the increased integration of technology in everyday life, the discussion about the so called 21st century skills emerged (Wing, 2006), bringing CT as an educational topic to the forefront (Grover & Pea, 2013). Holding CT competency provides an individual with the ability to deal with complex problems (Tang et al., 2020), allowing the characterization of CT being "a universally applicable attitude and skill set" which can be cultivated from young ages (Wing, 2006). Thus, CT is not only a skill-set but mainly a mentality.

Early Childhood Education (ECE) is a fundamental stage for a child's development during which acquired skills pertaining to the cognitive, social and emotional domain take place. For many researchers ECE is an ideal initiation point for cultivating CT and early exposure to CT is important to ensure young children master ideas and habits of mind to shape their learning (Su & Yang, 2023). In this age group, children transition between concrete and abstract processes and develop higher-order thinking processes. Active experiences provision to provoke thinking appears to support this transition. CT, often through programming, allows children to acknowledge the process of automation and understand that it results in a set of a clearly defined instructions which drive a device. This process may lead children to start solving real world problems through systemic steps, ultimately becoming technology designers rather than passive users.

Another pilar of the approach is educational board-games which can create a learning environment which is attractive for the children and is authentic (Ali et al., 2019), allowing the implementation of transdisciplinary approaches for the development of multiple competences (Strode, 2019). Moreover, board-games' utiliation in ECE fosters the development of social (Eriksson et al., 2021; Tsapara & Bratitsis, 2021) and 21st century skills (Ambarita et al., 2020; Bratitsis et al., 2021), positively impacts learning motivation and facilitates the achievement of curriculum objectives.

In this paper, a board-game called CTHINK.IT is described (Busuttil et al., 2023). It aims at introducing CT to ECE children (4-8 years old). The paper is structured as follows: first, the main outcomes of a conducted literature review is briefly presented. Then the board-game is described and some preliminary findings from its pilot testing are presented.

## 2. Theoretical Framework

Two main pillars guide the idea behind the project; CT and board-games in ECE. First a systematic literature review on both areas was conducted.

The literature reveals many divergent CT definitions (Haseski et al., 2018). They focus on problem-solving, technology, thinking, individual and social qualities or learning by doing, following Papert's (1980) approach of Constructionism. Although often CT development is supported by programming, Voogt et al. (2015) highlighted that it expands further than that. Wing (2006) first considered CT as a broader notion that involves problem solving, but also understanding and systematizing human behavior via computer science concepts, also involving systems design. In a revised CT definition Wing (2010) included thinking processes as a core constituent.

The review examined how CT is treated in ECE, also searching for classroom activity types (Bratitsis et al., 2024). Different approaches were followed. One major category is implementing unplugged activities separately or combined with a digital device (e.g. robot) or a programming platform, appropriate for these ages. Due to the connection of programming with Mathematics and Sciences, a connection between STEM and CT teaching can be noticed. Overall, the unplugged approach is portrayed as a good strategy for introducing CT to young students. This in fact emerged as an ideal pre-cursor to further programming and problem-solving tasks that include both robotics and programming, which both require complex thinking abilities to understand abstract concepts and solve problems. Unplugged activities have the potential to establish a foundation for educational methods based on problem-solving and constructive learning, which involve the learner's active engagement with the environment on both physical and mental level to construct and scaffold their understanding. Such activities include hands-on robot play (Storjak et al., 2020) or spatial movement (Sung et al., 2022), before moving to programming environments such as Scratch (Lee et al., 2020) or programmable devices (Metin, 2020).

Ultimately, unplugged approaches provide some sort of embodied cognition that allows the physical enactment of the CT concepts, which seems to be effective for children in understanding these abstract concepts. However, despite the perceived value of unplugged approaches to CT, there seems to be a dearth of unplugged resources which can be used for CT in early childhood education, and this calls for the need of further research in this area to create and develop more unplugged resources that can continue to help and support the acquisition of CT skills in early childhood education.

Several studies utilise coding in ECE. Games such as Kodable (Lennon et al., 2022) or game-like activities platform (Montuori et al., 2022) are utilized. Other studies utilize tangible programmable objects such as Osmo Coding Awbie (Liu & Iversen, 2022). Mainly, programming environments such as ScratchJr (Kyza et al., 2022) or Viscuit (Watanabe et al., 2019) have been utilized for coding-based CT approaches in the early years.

Another approach is using robotics. Overall, 51 papers were found, focusing on robotics CT approaches. Of them, 35 papers exclusively focus on robotics CT implementations, 11 combine robotics with unplugged activities, 3 combine robotics with programming, and only 2 papers explore the combination of all three methods. Several robotic devices have been utilised, including: KIBO (Bers et al., 2022), BeeBot (González & Muñoz-Repiso, 2017), Cubetto and Botley (Silvis et al., 2022).

The final conclusion of the review was that unplugged activities seem very effective in young ages as they allow some kind of embodied cognition, allowing CT concepts to be physically enacted and thus better acquired.

The second pillar of the review examined board-games utilization in ECE. Combining hands-on practice with complex knowledge, board-games seem to be a perfect fit for children's creativity, imagination, curiosity (Uribe & Cobos, 2014). For Tsai et al. (2021), board-games allow students to peer learn, focusing on interactivity and student-centered learning. Board-games have features such as rules, goals, tangible experience (e.g. through pawn movement or cards), turn-taking, interaction (also of a social nature), competition, collaboration and problem solving, to name a few of them. Thus, board-games within educational context can facilitate the cultivation of various competences (Tsapara & Bratitsis, 2024).

The review revealed that board-games are utilized for CT cultivation in ECE. Bratitsis et al. (2021) taught internet related issues through a board-game in Kindergarten. Machuqueiro & Piedade (2022) analysed several studies in which board-games acted as unplugged activities for CT teaching. Overall, 11 papers were found studying board-games utilization for CT in ECE (Bratitsis et al., 2023).

Finally, the official curricula of three EU countries were studied in order to identify existing approaches, both on theoretical and practical level, including proposed activities. This allowed the consortium to reach a conclusion about the CT model to be followed and consequently be treated through the board-game which was designed and is presented in the next section.

## 3. The CThink.It Board-game

The systematic literature review allowed to gain valuable insights on the current trends of CT approaches and board-game utilization in ECE. The conclusions derived from this study (Bratitsis et al. 2023, Busuttil et.al 2023) led to the decision to incorporate a 4-element approach to CT, including: abstraction, decomposition, pattern recognition and algorithms. This simplified model seemed to be a better fit for younger ages.

A board-game was designed, called "Mystery at the Museum". This game places the player in the role of a detective hired to solve a mystery. The player will have to use basic competencies of CT to: a) identify a lost item in the museum, b) discover its owner, and c) return it to its owner. It comprises 4 levels. The game is played collaboratively or competitively, with the facilitation of an adult (teacher/parent). Several combinations of collaborative vs competitive mode can be applied (e.g. pupil groups playing levels 1-3 in parallel and then come together to compete in level 4). The game includes variations that result in different experiences each time it is played.

Mystery at the museum was designed for children 4-8 years-old. Ii incorporates features that differentiate difficulty, according to game level and players' age. Depending on the players' ability only some levels might be completed, however for older players, all 4 levels with more difficult puzzles should be played.

The game starts with an invitation to the detective by the museum director to locate the owner of a lost item, a toy left behind by a child in the previous day. In level 1, a card is randomly selected from a deck, containing two images from a specific division of the Museum. One image depicts a time before the opening of the museum and one after the closing time, on the day the item was lost. By comparing the two images, the player should identify the lost item (Figure 1).

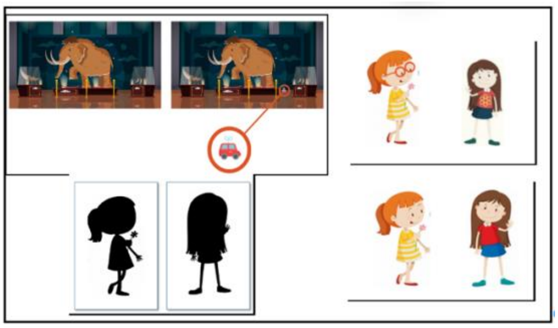

**Figure 1: Level 1 and Level 2 image examples.**

In level 2 (Figure 1), an introduction card explains that security camera footage is available for the player to identify the owner of the lost item. In the invitation it is noted that the lighting was not very good and shadows may appear in the footage. A card is selected from the Security Cam Deck, showing the shape/shadow of the toy owner. Having in mind the shadow in the card, the player has to look at other footage from the entrance camera with clear images to narrow down the possible toy owners. At this point, the player takes another card from the Testimonies Deck from people that were present at the Museum that day. This card provides new clues, such as whether owner wore spectacles, their hair colour, if they had a flower, etc. The player has then to identify the person from the deck based on these characteristics

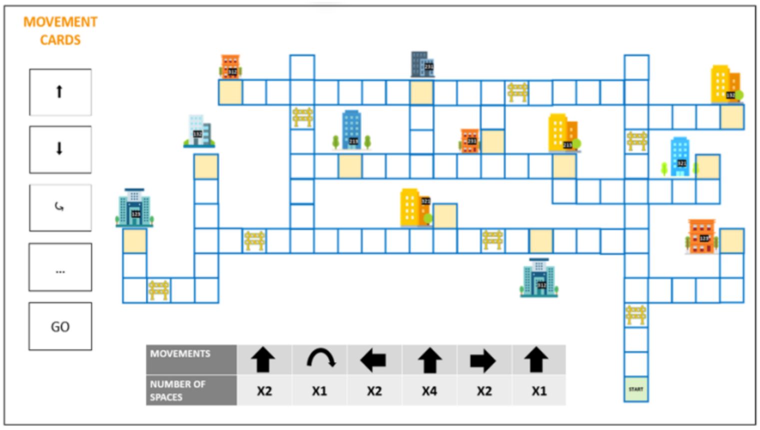


**Figure 2: The city map and movement cards.**

In level 3, the museum director provides a city plan to the detective who then has to identify the item owner's house and return it. The map includes 3 spots with a museum symbol which supplies clues for finding the owner's house. These cards are placed by the teacher in any space in the board (e.g. can make it to be closer to one another to make the difficulty level lower or make the game faster). The player also gets initial Movement Cards (Figure 2) which can be re-used in each turn. To move around the city, the player must compose algorithms representing the path they must take on the map. The algorithms created must be able to fit a pre-established grid, the Programming Bar (Figure 2 – bottom), representing a minimum of length. Player can create as many algorithms as needed to reach the final destination. The grid has 6 movements and it is not allowed to use less in each turn. There is also a jump card which can be used for jumping over obstacles, as an increased difficulty feature. For younger students, the algorithm can be designed on the city map directly.

The players must first visit all the spaces with the symbol "?". Upon landing on a space with the symbol "?" the player gets a Clue Card. There are two sets of Clue Cards, one with numbers and one with colours. The number cards form the door number and the order in which they are picked is the order by which the numbers are on the door. The teachers must take 2 cards from this set and place them on the board (museum cards). The colour cards represent the colour of the building – either Blue or Orange. One of these cards should be placed by the teacher on the board (museum cards). With the 3 clues gathered, the player must guess which is the correct building and visit it tolook for the owner's flat. This level can further be played/replicated in the classroom by utilizing robots (e.g. BeeBot) or by asking the students to move around a mat version of the map themselves.

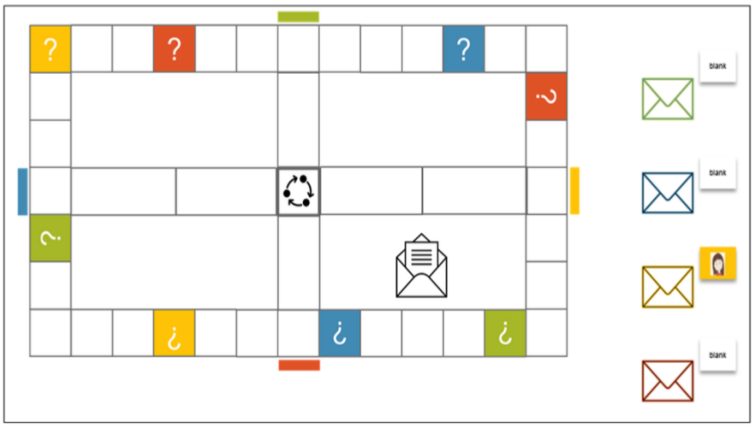

**Figure 3: Level 4, inside the building.**

In level 4, the player enters the building. There are 4 envelops with different colours (yellow, green, red and blue) representing the different doors/apartments in the building. Additionally, there are 4 character cards – 3 blank cards and one with a child. The teachers secretly puts one card in each envelope. The door with the envelope containing the character card leaads to the toy-owner (Figure 3). Then, players put their pawn in the centre of the board. Each player rolls a die in turns, moving around the board, in whatever direction chosen. This means that player can choose a new direction after rolling the die, but must follow it for that turn. If the player lands on "?" he/she picks a question from the respective colour pack. If it is answered correctly, the card is kept as a token, otherwise it is returned at the bottom of the pack. By rolling a "6" an additional die roll is earned. After collecting all 4 coloured tokens the player can "knock" at any door and reveal the corresponding envelope to try finding the toy owner. For that purpose, the player must go to that door, only after acquiring four tokens, one of each colour, by landing to the space in front of it. If the envelops reveals the child (character card), the payer wins. If not, the player loses the token of that door and needs to re-acquire a token set of 4 colours. To knock on any door, the player must always have the 4 coloured tokens. At any point in the game, the player may collect more than one card of the same colour, but to open a door they must have the 4 different colours. There is a special space at the centre which by landing on it the player is teleported to the door of their choosing.

The winner of the game is the player who finds the child and returns the lost item to them. A group of children may, of course, act as one single player and collaborate throughout the game. The questions in level 4 are all exercises directly connected to the 4-attribute model of CT and connected to the theme of the story (museums and toys).

A set of 11 lesson plans was designed to complement the game, serving as a foundational precursor to the board-game. These lesson plans are designed to introduce children to the major components and learning objectives addressed in the game, preparing them for gameplay by familiarizing them with essential concepts. Each lesson plan is structured to progressively introduce key computational thinking concepts in an engaging and interactive manner. The plans cover topics such as algorithmic thinking, problem-solving strategies, logical reasoning, decomposition and pattern recognition.

Through hands-on activities, group discussions, and guided exercises, students explore fundamental computational thinking skills. They learn to identify patterns, create step-by-step sequences, and analyse problems systematically. Moreover, the lesson plans emphasize the importance of collaboration and communication, encouraging students to work together to solve challenges and share their ideas.

By the end of the lesson series, students are equipped with the foundational knowledge and skills necessary to engage effectively with the board-game. They acquire a solid understanding of the core concepts and are ready to apply them in a game-based learning environment to further develop their computational thinking abilities.

## 4. Pilot Testing

The game is being pilot tested at the time this paper was written. Some preliminary data have already been analysed and discussed upon in the final section of the paper. It is to be noted that the game is being tested as a mock up and the final graphical design will be implemented after the completion of the pilots. The main aim of the pilot testing is to use the designed material (game and lesson plans) to collect feedback for improvements and refinement. The testing regards the following axes: a) The lesson plans, b) The game, and c) Learning assessment (optional).

The pilot studies are being conducted in three partner countries, namely Greece, Malta and Portugal. Prior to the pilots, teachers underwent training which focused on familiarizing themselves with the CT concepts and approaches, the game itself and the designed lesson plans. During the training sessions, the participating teachers actually played the game. Each of them is required to pilot test at least two lesson plans and collect feedback for the following aspects: a) Lesson plan clarity (steps, structure, guidelines), b) Goals (easy to meet, interdisciplinarity), c) Applicability in class (time required, class management, etc.), d) Perceived usefulness, and e) Perceived success (students learned – optional). For the game itself, it is to be tested with the students in order to collect two levels of feedback: student and teacher feedback. Regarding the students, the aspects for which data is collected are: a) Game concept and clarity, b) Game Mechanics, c) Game difficulty, d) Group playing and collaboration, e) Perceived Enjoyment (how much did the students like playing the game), and f) Positive & Negative aspects (1 thing they like or not). From the teachers' side, the requested feedback concerned is: a) Game concept and clarity, b) Game Mechanics, c) Applicability of the game in class (time required, class management, space required, ability to play in intervals, etc.), and d) Perceived usefulness. As an optional level of feedback collection which is not examined in this paper, a learning assessment was proposed to be carried out.

For each set of data, appropriate templates were designed and distributed to the teachers. Regarding the process, at least 3 teachers from each country are required to test the game and material, implementing a different lesson plan with the participation of at least 10 children. A teacher's diary was proposed to be kept for keeping notes deriving from observations during the testing. The data collection templates are being filled in right after each pilot testing round has been completed.

## 5. Discussion and Future Plans

The initial findings from the pilot provided valuable insights. Notably, the study revealed that the collaborative version of the game was more effective than the competitive version in a classroom setting. In the competitive mode, students who completed their tasks quickly experienced extended waiting times compared to others. This led to challenges for some teachers in managing the class while ensuring everyone remained on task. Specifically, when played with larger groups, some teachers found it difficult to oversee each group's progress and provide necessary guidance while also progressing through the game explanation. Conversely, in the collaborative mode, where students worked together towards common goals, the game was more manageable, regardless of group size. In this mode, the teacher played a crucial role in monitoring group dynamics, ensuring everyone took turns and remained inclusive of one another.

Furthermore, subsequent runs of the game with the same students showed significant improvement, indicating that familiarity with the game mechanics led to increased focus on learning outcomes and enhanced computational thinking competencies. This suggests that repetition and practice are key factors in the effectiveness of using the game as an educational tool.

One noteworthy observation was the enthusiastic reception of the game by students, who exhibited high levels of motivation and engagement throughout gameplay. This positive response suggests the game's potential to effectively engage students in computational thinking activities.

However, several challenges and areas for improvement were identified during the pilot testing. Firstly, it was noted that the board and pieces were too small, indicating the need for size adjustments in the final design. Additionally, the introduction of a step-on mat as the game board was suggested to accommodate younger children and encourage physical engagement with the game.

The integration of a narrative backdrop was found to increase student engagement and provide context to the learning experience. Levels 1 and 2 progressed smoothly, emphasizing the importance of the teacher's questioning techniques in guiding students through the game and maximizing learning outcomes.

In contrast, Level 3 presented challenges, especially in competitive mode, where students struggled with the complexity of using the program bar to code actions. Some students had difficulty visualizing the outcomes of their actions and translating the code execution into movements on the board. This challenge was less pronounced in the collaborative version, as no program bar was necessary; instead, players directly placed the required sequence of commands on the board. After an initial adjustment period, students quickly adapted to effectively using commands in this mode.

Level 4, which involved chance elements with dice rolls, occasionally led to prolonged gameplay due to the requirement for specific combinations. In relation to game rules, for this final level, it was suggested that allowing movement both forward and backward in the same turn could be an improvement. Previously, the rules permitted movement in both directions but not within the same turn. This adjustment could lessen frustration, promote strategic thinking, and speed up gameplay.

In conclusion, the preliminary findings suggest that the board-game holds promise as an effective tool for teaching computational thinking skills. Addressing the identified challenges and implementing suggested improvements could further enhance the game's educational value and usability in classroom settings.

The pilot tests are still being carried out while writing this paper. More feedback from more countries will be received, including more structured analysis of observation journals and data collection instruments. The expected results will be utilized for improving game mechanics but also proceeding to the final graphical design of the game, addressing the recorded needs for size, colors, etc. Based on the teachers' feedback, the final version of guidelines for the lesson plans will be written.

Other future plans include quasi-experimental approaches for measuring the learning outcomes in order to assess the learning potential of the board-game further. Considering that there is limited availability of educational material for ECE, there is the intention of translating the material in more languages and further testing its connection to national ECE curricula which integrate CT.

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