



## Developing Computational Thinking Ability in Early Childhood Education: The Influence of Programming Toy on Parent-Children Engagement

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### ABSTRACT

Technology and smart devices have become ubiquitous staples in every aspect of human life. Given the rise of computation in everyday life, introducing technology to early childhood students requires exposure to logical thinking and problem-solving skills through programming approaches or computational thinking. This research addresses an inquiry into a comprehensive elaboration of the development of early childhood computational thinking. A novel programming toy was introduced as an educational tool based on designated themes in accordance with early childhood education curricula. Five stages were conducted to reveal parental and child engagement in robotics activities and later, interviews were conducted on children's cognitive development from the parents' perspective. Children were observed exploring in various ways by concentrating and paying attention, doing the given activities and expressing their excitement and happiness. The notion that children learn from their social network environment was highlighted by the way in which the children involved in the KARIN programming toy's hands-on activities were driven to be more actively engaged in the exercise. In addition to parent-student engagement, the use of the KARIN programming toy helps to shed light on how students in early childhood learn while away from their social relations during a pandemic.

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## 1. INTRODUCTION

Technology and smart devices have become ubiquitous staples in every aspect of human life. Since millennials live in a software-driven society, they are not separated from technological advances (Cansu & Cansu, 2019) that help them interact with their surroundings. Given the rise of computation in everyday life, introducing technology to early childhood students may not be beneficial unless they are exposed to logical thinking and problem-solving skills through programming approaches or computational thinking (García-Peñalvo & Mendes, 2018). Indeed, it has been suggested that such skills should complement reading, writing and arithmetic as fundamental skills used by everyone in the world (J. Wing, 2011). Computational thinking involves formulating a problem and its solution so that these can be effectively represented by information-processing agents (J. M. Wing, 2008). Researchers recognise the importance of computational thinking in controlling and managing cognitive activities and for understanding and solving problems in various contexts in all disciplines beyond computer science (Grover & Pea, 2018; J. M. Wing, 2008).

The definition of computational thinking may vary among researchers. J. Wing (2014) and Yadav, Mayfield, Zhou, Hambrusch, and Korb (2014), for example, argue that computational thinking is a mental process used to formulate problems and express solutions in computer terms that can be carried out effectively. On the other hand, Furber (2012) suggests that computational thinking is the process of recognising aspects of computing in the world that surrounds us and applying tools and techniques from computer science to understand and reason natural systems and procedures as well as artificial systems and processes. At the same time, Hemmendinger

(2010) argues that computational thinking teaches students how to use computing to solve problems, and create and find new questions that can be explored in a useful way.

It is important to deliver learning aimed at improving computational thinking skills from early childhood. As Resnick and Silverman (2005) state, children need to have the ability to think creatively. Early childhood is a time of rapid growth and development, when children are extremely curious, have a strong desire to learn and get to know the environment in which they live. Children will likely be motivated to discover if they receive the proper stimulation. Direct experience, for example, can be provided to children as the best learning stimulation. This is in line with Piaget (1952) opinion that to master new knowledge about the environment, children in early childhood need direct experience to develop their understanding. The notion is also reinforced and supported by Papert (1996) constructs, which are themselves rooted in Piaget's (1954) constructivism and convey the idea that children actively build and develop their knowledge through experiences and a 'learning by doing' approach to learning-related activities. In contrast to Piaget's theory, however, this was developed to explain how knowledge is constructed in the individual's mind. Papert developed it to focus on the methods of internal construction supported by constructs on the external, including through the use of computers and robots. A constructivist teaching approach gives children the freedom to explore their interests through technology (Bers, 2008).

In light of Piaget's constructivism (Afari & Khine, 2017), robotics may serve as an appropriate educational tool for use in early childhood as one of the ways in which children build knowledge by manipulating artefacts. Educational technologies such as programming toys, robotics kits, board games and augmented reality (AR) (Ching, Hsu, & Baldwin, 2018) can potentially help facilitate the development of Computational Thinking skills. Robotics, for example, can benefit early childhood learning due to its distinctive characteristics. Robotics enhances student-teacher engagement (Kim, Kim, Yuan, & Hill, 2015) since hands-on work involving assembly and programming is considered to be its motivating nature. Robotics introduces holistic training to students and encourages interdisciplinary STEAM learning (Jurado, Fonseca, Coderch, & Canaleta, 2020). It successfully addresses the abstract use of computational thinking that is traditionally presented with a particular difficulty.

Amid the ubiquitous benefit of robotics to facilitate computational thinking development in early childhood, little in the way of literature has offered a comprehensive elaboration of the development of computational thinking in early childhood in developing countries. The problematic aspects arguably relate to a lack of essential resources to deal with social, ecological, technological and economic inequalities. To be more specific, a lack of skills among stakeholders to develop and research the technology related to increasing the attractiveness of students and teachers undertaking technology-based learning (González, Jiménez, & Ovalle, 2010). Conventional practices, infrastructure and specialisation are considered the main barriers to integrating novel ICT into the educational systems of developing countries (Aksal & Gazi, 2015). The curricula of most schools in developing countries are often designed to encourage traditional lecture-based teaching methods with no instructional strategies that facilitate the involvement of all students (Gyimah, 2011). Despite the inclusion of computational thinking in Indonesian early childhood education curricula, in addition to the lack of current validated instruments for assessing CT ability in early childhood (Relkin, 2018), teachers' technology efficacy remains a significant obstacle to the wider application of computational thinking in schools (Wahyuningsih et al., 2020).

While teachers may be unfamiliar with technology-based educational tools, a novel programming toy was introduced on designated themes in line with early childhood education curricula. This paper therefore sheds light on parent-students while applying KARIN programming within the pandemic setting. Specifically, this research investigated the pattern of social knowledge construction developed through the application of KARIN programming within the pandemic setting.

## 2. METHOD

The research introduced KARIN, a novel programming toy, as a learning buddy for early childhood. Similar learning modules have also been introduced as computational toys (Hamilton, Clarke-Midura, Shumway, & Lee, 2019). KARIN comprises a set of components: a cubicle programming toy, a playground based on a particular theme and illustrated learning instructions. The KARIN robot was designed to reflect the characteristics of early childhood in terms of its dimension and character. The instructions and playground were designed according to the material introduced in the session, such as animals, plants, fruits, planets, etc. The total of five sessions lasted for an average of three days.

Initially, the research was designed around the conducting of an activity by teachers and students in a school setting. However, the closure of public schools during the pandemic prevented the activity from being carried out at school. Therefore, researchers conducted the research activities at students' respective homes. In the absence of teachers, parents and other family members helped the students run the activities. The study involved five students from various regions of Central Java, reflecting the restrictions on travel and gatherings in Indonesia during the pandemic. The students were between five and six years old and were accompanied by at least one family member. As required by the ethics committee (Peters et al., 2020), the parents signed written consent for their children to participate in the research.

#### a. Learning Model

The research was interpretive (Walsham, 2006, 2014). Learning activity models were constructed using the International Society for Technology in Education (ISTE) standard, while the observational indicators refer to Atmatzidou and Demetriadis' procedures (2016) that determine the five aspects of computational thinking skills, namely abstraction, generalisation, modularity, decomposition and algorithm. As elaborated in Table 1, the activities undertaken with KARIN had an associated CT skill.

Table 1. Computational Thinking Ability

Activities Using KARIN	Description	CT Skills
Participants identified pictures of the characters on the board area, learnt how to run the robot, and saw the function of each robot component.	The process of simplifying things from complicated matter to make the problem is more comfortable to think about (J. M. Wing, 2008).	<i>Abstraction</i>
Participants extended the solution by trying other ways to run the robot from one point to another (students could show two different routes).	Transferring the problem-solving process to become more diverse (Barr & Stephenson, 2011).	<i>Generalisation</i>
Participants ran the robot with the program according to the target point using a correct, efficient and effective program.	Jot down specific and explicit step-by-step instructions for carrying out a process (Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012).	<i>Algorithm</i>
Students developed or reconstructed previously created programs to solve other challenges.	Developing a problem-solving process (Barr & Stephenson, 2011).	<i>Modularity</i>
Students re-iterated the problem-solving steps and could distinguish problems from the easiest to the hardest.	Splits problems into small clusters that can be solved separately (J. M. Wing, 2008).	<i>Decomposition</i>

The learning model was split into five sessions. Sessions 1 and 2 contained an introduction to the KARIN robotics used, while Sessions 3, 4 and 5 included assignments that the students had to complete. Table 2 contains a description of the activities in each session.

Table 2. Learning Activity

Session	Activities
1	Introducing KARIN robotics to students, accompanied by parents
2	Running robots with parental supervision
3	Case assignment by moving the robot in a back and forth motion
4	Case assignment by moving the robot forward and turning
5	Case assignment with more complex motions and longer tracks

#### b. Child Observation

The first data collection was conducted by observing the participants' activities (Conroy, 2017) associated with particular CT abilities, as mentioned in Table 1. Observation was conducted by looking at the five computational thinking skills: abstraction, algorithm, decomposition, generalisation and modularity. In Sessions 1 and 2, abstraction skill was observed. If the children demonstrated the ability to meet at least half of the abstraction criteria, they continued to Session 3. In Session 3, the children were required to demonstrate ability in the skills of abstraction, algorithm and decomposition before continuing to Session 4. In Session 4, the researchers sought to observe the children's ability in abstraction, algorithm, generalisation and modularisation. Finally, in Session 5, the researchers sought all five CT skills. During the observation, there was no guarantee that all five of the CT skills would be displayed as a sequence. The comments show the category of computational thinking skills, ranging from proto programmer to fluent programmer.

### c. Parents' Interviews

The second research method was a semi-structured interview (Schamber, 2000) conducted with parents. This was intended to determine the response to the use of robotics in developing computational thinking skills. The list of questions in the interview adopted the heuristic evaluation development, while the design of educational robotics systems (HEDDERS) comprised the aspects of cognitive workload, challenge, adaptability, interaction, level of automation, collaboration and communication, feedback, the comfort of the physical setup, enjoyment and aesthetics, transparency, active learning, relevance, reflection support and computational thinking (Giang, Piatti, & Mondada, 2019).

## 3. RESULT AND DISCUSSION

This study explored the impact of using KARIN programming toys on the development of early childhood computational thinking. Amid the closure of schools and restrictions on people gathering, the designated research activities that should have been performed by teachers were instead carried out at students' homes. In this regard, the absence of teachers engendered a new understanding of the relationship between the students and their parents or family members in response to the research inquiry. The research led to the following question.

RQ: How do educational robotics facilitate early childhood learning development?

The analysis and synthesis of the data collected during the research answered the research questions posited in the study, as suggested in the following.

An understanding of the role of educational robotics in influencing students' development was constructed from an analysis of the interviews with parents. Based on the parents' accounts of the children's reaction to the KARIN programming toy, the study suggests three primary constructs.

- a) Children are gradually developing their cognition.

In response to this, Parent C expressed that:

*'After being explained, there may be a few obstacles, but as it was progressing, children answered the challenges.'*

This statement highlights that the children's learning process with KARIN was not straightforward. Instead, their learning phases represent the development of their cognisance, alongside the stimulus received from their environment.

Relevant to the work of Lumsden (1994) and Piagetian theory, children learn gradually in line with the maturity of their cognitive development. Children learn from any means that is concrete and tangible, which their surroundings can sense. Lind (1998) explains that children learn by grasping their environment and exploring potential ways to learn from it. From birth onwards, children learn and seek solutions to the problems they face.

- b) Children correlate learning experience with their real-life surroundings.

The resemblance of KARIN's playground and the characters in the learning module encouraged the children to further explore the characters and context of the programming toy, as expressed in the interview with Parent D.

*'It (KARIN) enticed children to learn since she founds that animals' name and type represented by the robotics toy. She was motivated to learn further about animals by playing with the robot.'*

Experience in a natural setting is vital for young children's development (Ernst, 2014) as this type of experience is believed to be essential for children's cognitive, social and physical development. Indeed, as children, cognitive behaviour is rooted in their understanding (Duit, 1998); as such, the children's activities brought their sensory experience into their own conscious and unconscious constructs. For example, children's mathematical and scientific concept is acquired through their active involvement with their environment (Lind, 1998).

- c) Children's learning is based on play

Play, care and well-being are well-known elements within early childhood pedagogy (Broström, 2017). Play is the principal way in which young children develop and learn and will always contribute to their

development. Moreover, Vygotsky (2010) and many other scholars emphasised that play always leads to a higher development level.

Such an idea was conceived by Parent C:

*'The module contributes to the development of my child's knowledge well because it introduces various animals through this robotics device so that children can learn while playing.'*

The creation of fun and joy from interaction indicates the utmost aspect of learning in a playset. In this research, the children explored in various ways by concentrating, paying attention and undertaking the given activities, which led to them expressing their excitement and happiness. Children enjoy exploring, observing and processing their environment in their own way (Eshach & Fried, 2005), although the constructs they generate from such processes may not always be relevant to the adult's way of thinking and teaching. This notion somewhat disregards the robotics device as the point of interest of this research. It may undermine the construct that the programming toy will be applicable for early childhood education. However, as advocated by Hedges and Cooper (2018), attempting to correlate children's achievement (or, in another case, shortcoming) by comparing one child's performance with that of other children would undervalue the richness of their engagement. Doing so may undermine the purpose of play and the ways in which children create meaningful engagement with their environment.

d) Children learn through their social learning environment

Since Solomon and Papert (1976) inception of Logo programming and Turtle robotics, children have been encouraged to learn by working on a hands-on learning object. While programming may seem a solitary activity, working with floor robotics requires the challenges to be carried out in groups; that is, the social aspects of learning involve personal and emotional facets. This connects the use of technology in computational thinking with learning paradigms associated with such social learning environments (Catlin & Woolard, 2014). The extent of the social abilities of early childhood students can be discerned from the evidence revealed in the research.

The notion that children learn from their social network environment was conceived in the interviews with parents. The parents noticed that their children's involvement in the KARIN programming toy's hands-on activities led to the children becoming more actively engaged in the exercise. For example, as recalled by Parent E,

*'(The activity) made children inquire about things that lead to dynamic interactions.'*

The children were therefore enticed to communicate with other people in their environment when responding to the stimulus from the KARIN programming toy. This finding was similar to one from a longitudinal study by Kory-Westlund and Breazeal (2019) who, when integrating a robot into the language learning of young children, found that the children's rapport with the robot stimulated them as learners to emulate the introduced behaviour in both a one-on-one setting and group interaction. This could serve as an insight into how to integrate technology such as the KARIN programming toy into a real-world educational context.

#### 4. CONCLUSION

This research has investigated the implication of using KARIN programming toys in the development of early childhood computational thinking. Faced with the absence of teachers from the intended design, the study revealed the relationship between the students and their parents or family members in response to the research inquiry. This research sheds light on children's phases of learning that represent the development of their cognisance alongside the stimulus received from their environment. Children correlate their learning experience with their real-life surroundings; as such, the children in this research were observed exploring in various ways by concentrating and paying attention, doing the given activities and expressing their excitement and happiness. Ultimately, the research revealed the extent of the social abilities of early childhood students, as discerned from the evidence. The notion that children learn from their social network environment was highlighted by their involvement in the KARIN programming toy's hands-on activities, which drove them to become more actively engaged in the exercise.

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