Chang, M. et al. (Eds.) (2019). Proceedings of the 27th International Conference on Computers in Education. Taiwan: Asia-Pacific Society for Computers in Education

A Case Study on How Children Develop Computational Thinking Collaboratively with Robotics Toys

Kay Yong KHOO
PT Lecturer, The University of Hong Kong, HK
kykhoo@yahoo.com

Abstract: This article reports on a case study on how robotics toys provide the affordances for developing computational thinking (henceforth abbreviated to CT) in young learners. The three key constructs of CT - coding, algorithm and decomposition - are used in the research. The study results identify how children interact with robotics toys collaboratively and acquire CT skills. Problems were presented to the children through planned non-routine and immersive collaborative group activities. The situations in which they externalized their inquiries and internalized new knowledge were observed. A detailed examination of the data collected was made to determine which robotics toys mediated the children's acquisition while seamlessly switching between individual and collaborative activities and has led to the development of a framework of the stages in CT learning designs. The article will include details and analyses of commercially available technologies for developing CT as applied with the young learners in the study.

Keywords: computational thinking, robotic toys, decomposition, algorithm, coding

1. Introduction

In an increasingly information-based society, CT is viewed as a foundation for coding (Baroutsis, White, Ferdinands, Goldsmith, & Lambert, 2019). Bers and her colleagues (Bers, Gonzalez-González, & Armas-Torres, 2019) showed that children as young as four years were able to engage in computational thinking activities using a robotics curriculum. These robotic toys hold the promise of creating direct and actionable interaction between the physical world and the electronic information and thereby representing a paradigm shift in exposing children to technology compared with screen-based human-computer interaction.

A review of the literature on the integration of robotic tools in the education of young children has mainly focused on exploring their interactions with such tools: (a) within the context of various content domains, such as maths, science, literacy and engineering (Lavigne, Orr, & Wolsky, 2018) and (b) in the context of familiarizing children with robotics concepts and computer programming (Misirli & Komis, 2014). there is no description of how teachers design young students' computational thinking lessons in the classrooms and provide robust empirical evidence of learning gains (Charoula & Nicos, 2019). The investigation of the development of young children's computational thinking through educational robotic toys remains in its infancy.

Table 1

The Constructs of CT

Constructs	Definition
Algorithm	refers to the arrangement of a step-by-step series of instructions to execute a task or solve a problem.
Abstraction	invites students to identify important information while ignoring unrelated or irrelevant details.
Pattern Recognition	involves the skill to look for similarities among and within problems.
Decomposition	involves the process of breaking down a problem into smaller manageable parts.

2. Research Design

The research was initially based on the four key constructs as in Table 1. The current study seeks to analyze informative and evidence-based findings to give an insight into how children acquire CT knowledge through collaborative activities with robotics toys. The activity theory was selected as the theoretical framework best applicable in the contexts of learning studied here (see Figure 1).

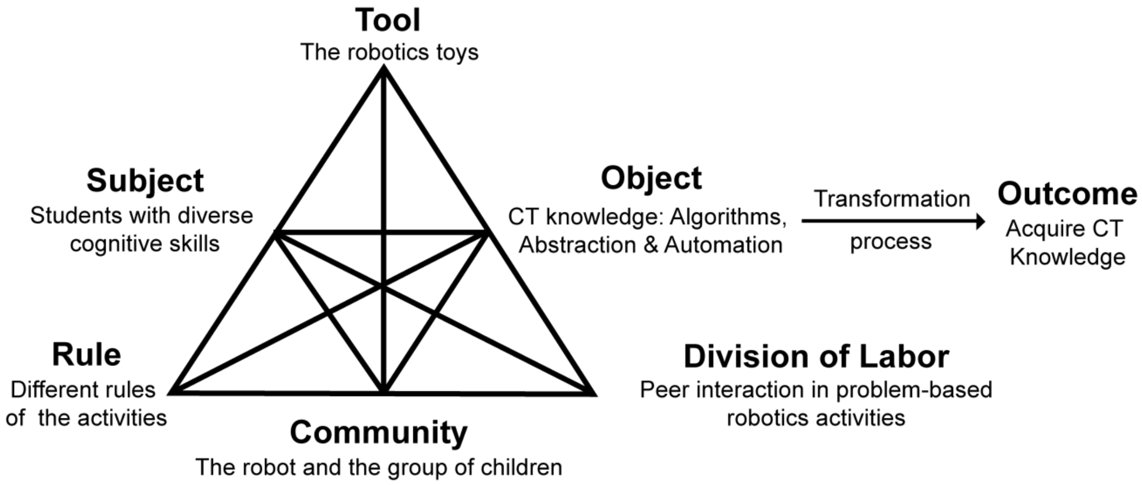


Figure 1: The research framework of the study

The study employs a qualitative research approach that is both descriptive and exploratory. Two research questions emerging from the literature reviews guided the data collection and analysis of the current study:

1. Which robots are best suited for learning various CT constructs?
2. What aspects must be considered when designing collaborative preschool classroom activities that use robots for the learning of CT?

Three types of robots - i.e., Mouse Robot, 3D Pen and OZO-bot - were selected based on their unique characteristics as claimed by the manufacturers matching the constructs in Table 1. The steps of the activities (see Table 2) were developed according to the framework of technology support for collaborative learning aimed at the learning gain of the constructs of CT.

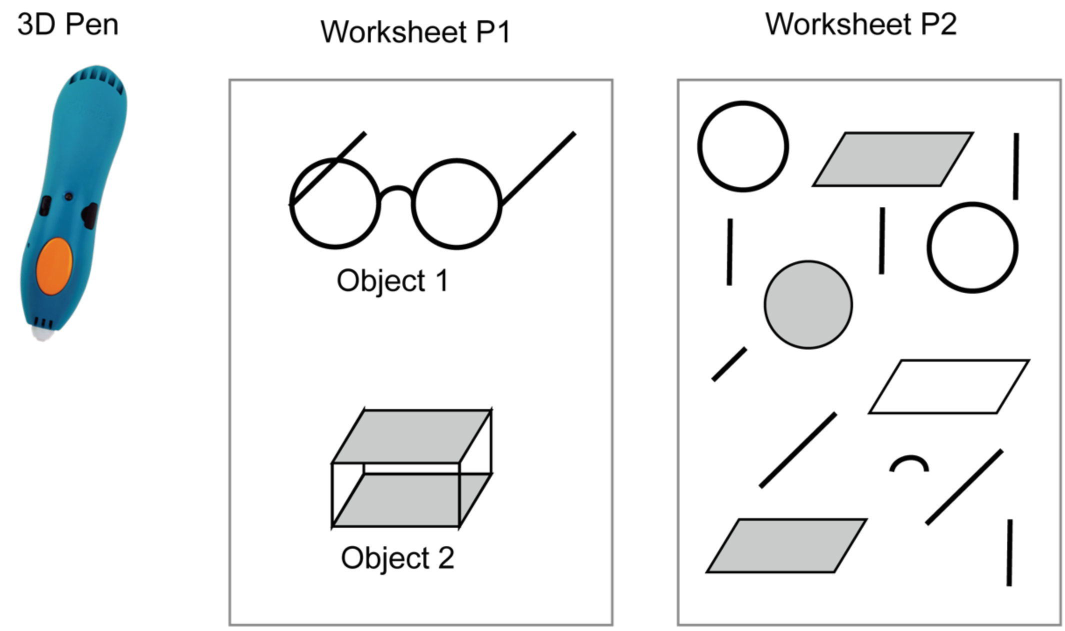
Table 2

The steps for conducting CT activities with the robot

Step	Description
1	*12 children in the class to be divided into 4 groups of three*
2	*The teacher demonstrates how to operate the robot through referral to the worksheets (Set A).*
3	*The teacher distributes the robot and worksheets to the group (Set B).*
4	*Each group completes the worksheets with the robot.*
5	*The teacher distributes the robots and worksheets to each child (Set C).*
6	*Progression to Step 5 is allowed only when Step 4 has been correctly completed.*
7	*The teacher awards a sticker to all students who manage to correctly complete the worksheet.*
Note:	*Sets A, B & C comprise the same type of questions but vary in the details.*

Table 3A

The Educational Robotics Activity (3D Pen)

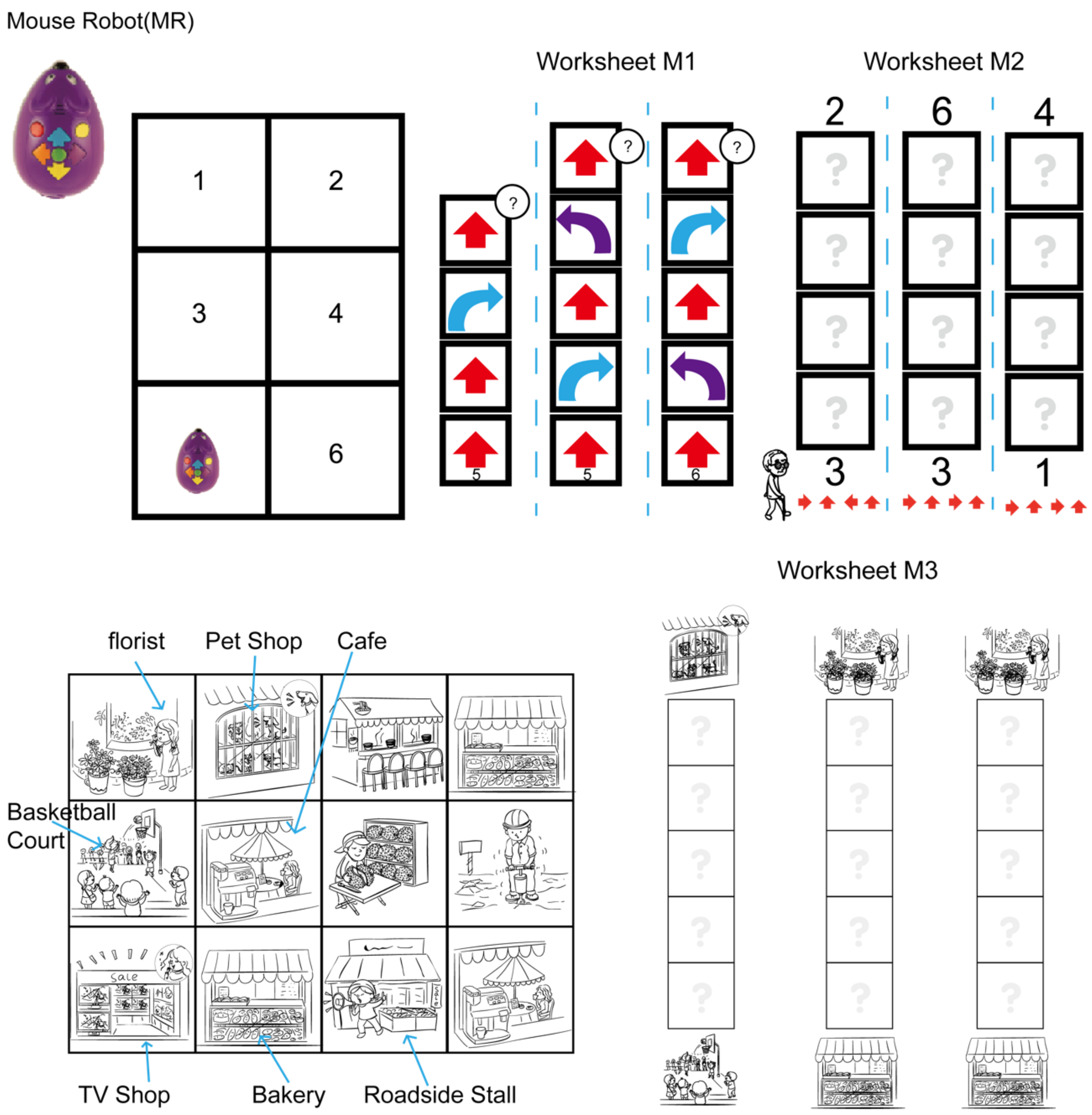


The activity: 3D Pen

Use the 3D pen to trace the items in worksheet P1. Subsequently, the participants form one of the spectacles (Object 1) using the items created. The participants only select the items necessary to form the object. Working individually, the participant then forms the next object (Object 2) (CT construct: decomposition).

Table 3B

The Educational Robotics Activity (Mouse Robot)



The activity: Mouse Robot

There are directional buttons at the back of the mouse, which enable it to move forward, left, right, backward, clear, execute etc.

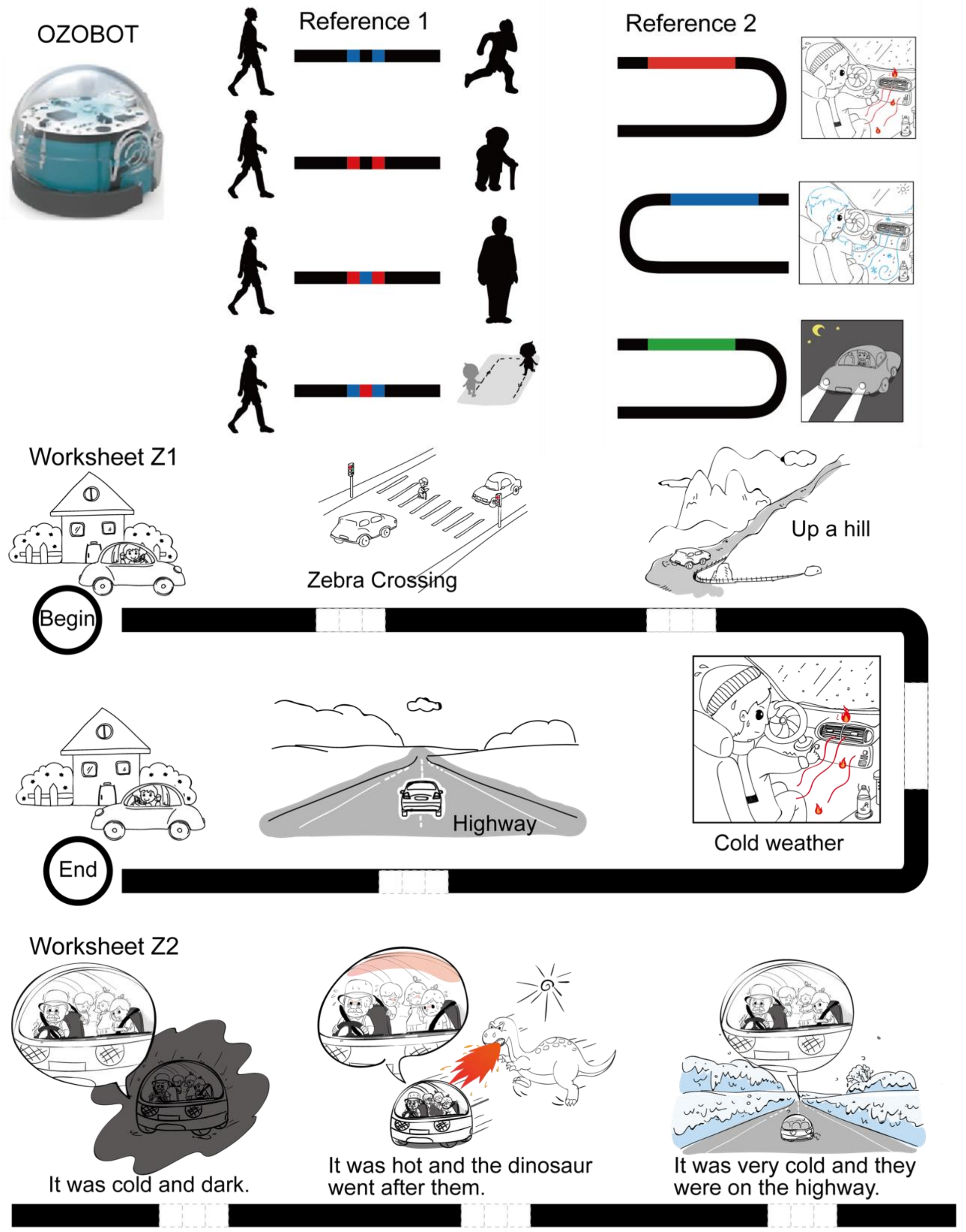
M1: There are 3 questions. Place the robot at 5 (or 6), code it and find out the result. Write the answer in the circle (CT construct: coding).

M2: There are 3 questions: Place the robot at 3 (or 1). Draw the arrows in the boxes. Program the robot to reach box 2 (or 6 or 4). Verify the answers and redraw (debug) the arrows until you get the answers (CT construct: algorithm).

M3: There are 3 questions: Place the robot in the box above the picture at the bottom of the first column. Draw the arrows in the boxes to enable the robot to reach the picture at the top of the same column. In the second and third columns, find two different ways to start from the same beginning point and end at the same ending point (CT constructs: efficiency and performance). Lastly, find out the least number of steps the robot can take to travel from the same beginning point to reach the ending point (CT construct: pattern recognition).

Table 3C

The Educational Robotics Activity (OZOBOT)



The activity: OZOBOT

There are 4 activities. The activities treat the OZOBOT as a car. The participants use different codes to set the OZOBOT as it travels.

Code references 1 & 2 in Table 3C inform the participants of the codes required in the activity; Worksheet Z1: The participants are required to apply suitable codes at different situations (CT construct: coding); Worksheet Z2: Each of the three situations presents two circumstances (it was cold and the road was dark; it was hot inside the vehicle and the occupants were being chased by a fire-breathing dinosaur; It was cold inside the car and the occupants were on the highway). The participants must choose a suitable code to be applied to each situation (CT construct: abstraction).

3. Results

This section will report the research findings as revealed by the data collected on the three participating children. The data collected based on activity theory led to the following four sub-activity triads:

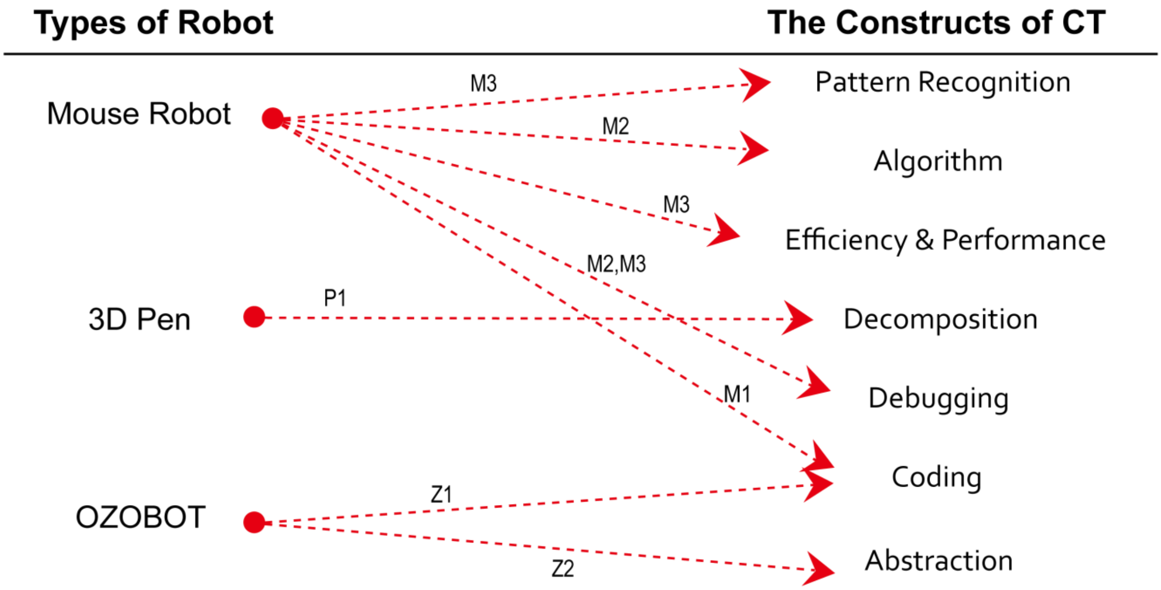


Figure 2. The skills of collaboration applied in different constructs of CT
M1, M2,M3,P1,Z1,Z2 are the activities as described in Table 3.

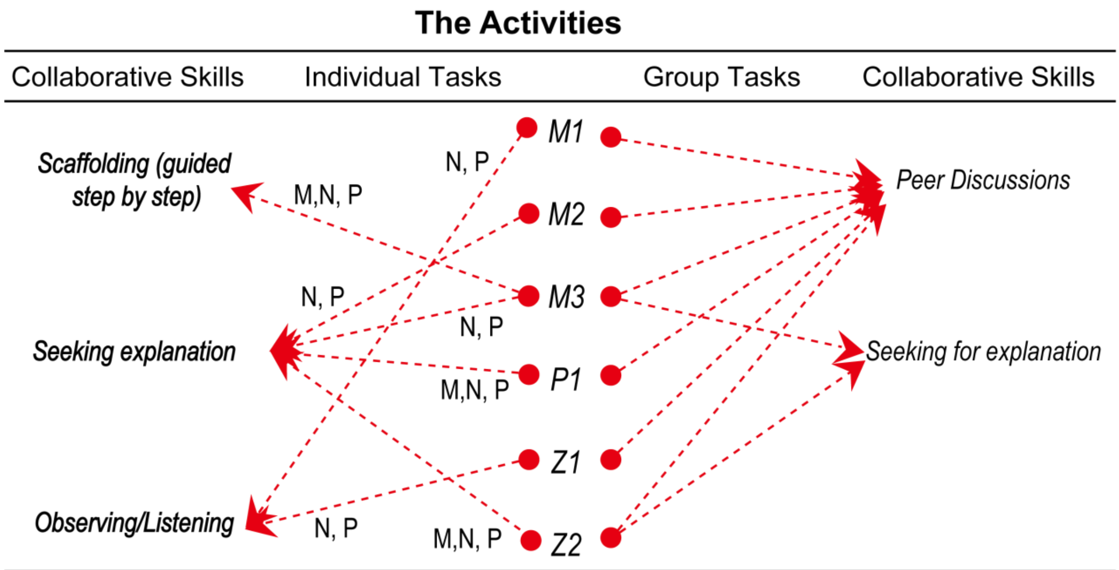


Figure 3. The skills of collaboration applied in both group and individual activities
Note: 'M' denotes Mary; 'N' denotes Nicole; 'P' denotes Peter;

Table 4

Analysis of the achievement of the participants as per Table 2

Steps/The constructs of CT	*Pattern Recognition*	*Algorithm*	*Efficiency & Performance*	*Decomposition*	*Debugging*	*Coding*	*Abstraction*
M1 (Group)						O (2)	
(Mary)						O (1)	
(Nicole)						O (1)	
(Peter)						O (2)	
M2 (Group)		O (2)			A		
(Mary)		O (2)			A		
(Nicole)		O (2)			A		
(Peter)		O (2)			A		
M3 (Group)	O		O (2)		A		
(Mary)	O		O (2)		A		
(Nicole)	O		O (2)		A		
(Peter)	O		X		A		
P1 (Group)				O (2)			
(Mary)				O (2)			
(Nicole)				X			
(Peter)				X			
Z1 (Group)						O (1)	
(Mary)						O (1)	
(Nicole)						O (1)	
(Peter)						O (1)	
Z2 (Group)							O (1)
(Mary)							O (1)
(Nicole)							X
(Peter)							X

Note: 'O' denotes 'the answer is correct'; 'x' denotes the answer is wrong/incomplete; the number in the parentheses denotes the number of attempts made; 'A' denotes the participant has attempted to respond with an answer.

3.1 Subject-tool-object

The participant was regarded as gaining the target skill only when their answer to the activity task was correct. The study of the 1st dimension sheds light on the first research question. Besides the four constructs of CT as determined at the beginning of the research, some additional constructs (see Figure 2) also emerged from the study - i.e., coding, efficiency & performance and debugging. Further, as observed in Figure 3, some of the interactions with the robotic toys might not have resulted in the gaining of new knowledge in CT. This indicates that other components that might have affected the learning must be further investigated.

3.2 Subject-community-object

Detailed study of the second dimension reveals that the participants managed to complete all the group tasks correctly (see Table 4). They were also observed to apply the collaborative skills of peer discussion and seeking explanation (see Figure 3) in their group tasks. Mary managed to learn all seven constructs of the CT skills as demonstrated in her individual tasks. However, Nicole and Peter did not gain the skills of decomposition, efficiency and performance and abstraction in their individual tasks although they had applied the collaborative skills of observation, seeking explanation and scaffolding (see Figure 3 and Table 4).

3.3 Subject-division of labor-object

In the third dimension, the progressive introduction of activities of the same set of robots was studied in relation to the individual tasks. CT is a process-based skill - it happened in time, not in space. Mary and Nicole completed their individual tasks correctly for M1, M2 and M3; Peter managed to complete M1 and M2 correctly but not M3; Mary had also completed Z1 and Z2 correctly but Nicole and Peter did not manage to correctly complete the latter; none of the participants managed to complete P1 correctly (see Table 4).

3.4 Subject-rule-object

In the fourth dimension, the rules that regulate the actions and interactions of the participants were studied (see Table 2). For every activity, the class started by listening to the teacher's briefing, which was followed by the group practice; the group had to complete the activity correctly before all group members were allowed to get their robots and worksheets for the individual practice. It was observed that all participants managed to complete all the group activities correctly (see Table 4). The participant was rewarded with a sticker if he/she completed the task correctly. All participants attempted all the individual tasks. As previously mentioned, the questions of the same type were set, but with minor changes in the details. The participants' levels of achievement varied in the different questions (see Table 4).

4. Discussions

The findings of research question two are analogous to a jigsaw puzzle. Through application of the activity theory, the four dimensions of analysis served as fundamental pieces of the puzzle. Once these pieces were fitted together, research question two was answered in totality. The analysis of the dimensions is summarized as follows.

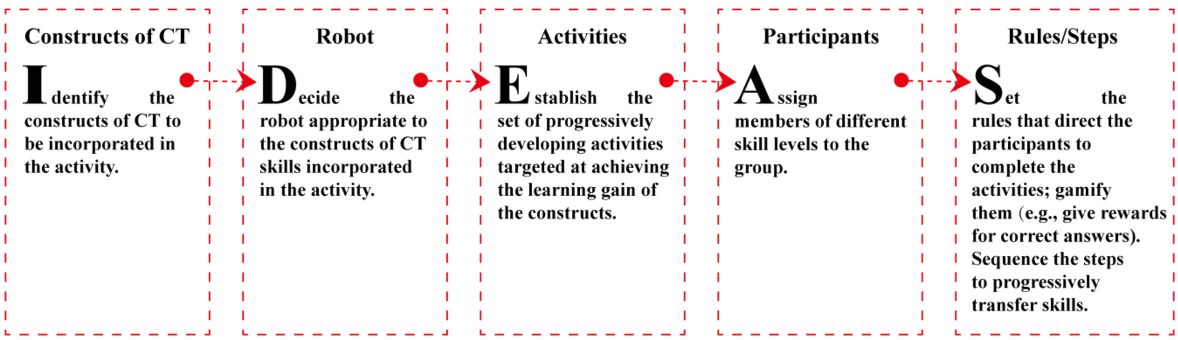


Figure 4. The Framework to Design CT Activities with Educational Robotics Toys

It is necessary to establish a more robust framework (as in Figure 4) to incorporate elements to consider in designing CT activities. The following framework emerges from the current research findings.

5. Conclusions

This paper syntheses relevant classroom activity designs in addressing CT as a general term that applies robots as the learning tools. The framework proposed here suggests aspects to be considered in appropriately designed classroom activities aimed at promoting learning gain within a constructivist model of CT skills building. Society now demands individuals have computer skills. Therefore, it is imperative that teachers find ways to integrate computational thinking into the classroom. While teachers have hesitated to pursue this because the associated terminology is unfamiliar, they can embrace the framework as suggested in the research finding for incorporating this type of thinking into their lessons.

References:

Baroutsis, A., White, S. L., Ferdinands, E., Goldsmith, W., & Lambert, E. (2019). Computational thinking as a foundation for coding: Developing student engagement and learning. *Australian Primary Mathematics Classroom, 24*(2), 10-15.

Bers, M. U., Gonzalez-González, C., & Armas-Torres, M. B. (2019). Coding as a playgrounf: Promoting positive learning experiences in childhood classrooms. *Computers & Education, 138*, 130-145.

Charoula, A., & Nicos, V. (2019). Developing young children's computational thinking with educsational robotics: An interaction effect between gender and scaffolding strategy. *Computers in Human Behavior, In Press*.

Lavigne, H., Orr, J., & Wolsky, M. (2018). *Exploring Computational Thinking in Preschool maths Learning Environments*. Paper presented at the Society for Information Technology & Teacher Education International Conference.

Misirli, A., & Komis, V. (2014). Robotics and programming concepts in early childhood education: A conceptual framework for designing educational scenarios. In *Research on e-Learning and ICT in Education* (pp. 99-118). New York: Springer.