# Using Robot-based Inquiry Learning Activities for Promoting Students' Computational Thinking and Engagement

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**Abstract:** Nowadays, an important robot in education as a strategy is the meaningful integration of technology to encourage the students to think and connect to a real-world situation. Moreover, robots offer an excellent tool for teaching and learning STEM disciplines that can be employed in a variety of subjects. Many studies focused on promoting students' conceptual knowledge. However, essential skills are crucial for the future success of students in the 21st century that is computational thinking refers conceptual foundation required to solve problems effectively. The purpose of this article is to descript the robot-based learning activity that utilizes robotics to enhance students' computational thinking. Our study has been designing based on a revised 5E learning model (engagement, exploration, explanation, execution, and evaluation). The evaluation study was conducted with 29 high school students in robot activities. The authors found that the framework not only positive supports the three dimensions of computational thinking in terms of concept, practice, and perspective, but also enhance the students' engagements toward robot activities.

**Keywords:** Essential skill, engineering education, educational robot

## 1. Introduction

Nowadays, an important educational robot as a strategy is the meaningful integration of robots into learning to encourage students to think and connect to a real-world situation. In the past decade, the use of robots for education has gained a lot of attention from researchers and educators. Many experiments used the mBot Robot kit, it is easy-to-use for students to get hands-on experience with graphical programming (Hutamarn et al., 2017; Zhong & Wang, 2019). In addition, a low-cost robot platform has been used to support student learning to develop hands-on open-source robots that is both inexpensive and reliable (Darrah, Hutchins, & Biswas, 2018; Tribelhorn & Dodds, 2007). Educational robots help students develop essential skills in the classroom that significant in connecting the concept to real life. Computational thinking (CT), which is one of the essential skills for students in the 21st century. CT is often regarded to be the basic skill of computer science is related to science, engineering, and mathematics disciplines. Additionally, an educational robot should be based on sound teaching and learning strategy (Özgür et al., 2017). Thus, the 5E learning cycle model-oriented learning cycle approach is a realistic, constructivist method of learning which employs students through a well-designed learning process (Dorji, et al., 2015; Piyayodilokchai et al., 2013). It remains a challenge to trigger students' constructing essential skills (Shute, Sun, & Asbell-Clarke, 2017); thus, it is crucial to afford students learning activities for constructing computational thinking. That is, the focus is on transforming teaching and learning strategy into a robotic context and on how the robot can be used pedagogically to promote students' essential skills.

Therefore, the main purpose of this study was the harmonization of an educational robot and learning pedagogy. Thus, this study investigates students' computational thinking and engagement resulting from learning activity following research questions:

1. Do students who participate in robot-based learning activities have computational thinking?
2. What are the students' engagements of the robot-based learning activities?

## 2. Literature Review

### 2.1 Robot-based Activities

Robotics is a branch of engineering that includes many subject matters that combine with science, technology, engineering, and mathematics or STEM disciplines. A robot is a machine used in variety of different tasks. A recent study has found that using a robot in education is increasingly being defined as a significant instrument of teaching and learning that integrated STEM education is crucial for the future success of students in the 21st century (Kelley & Knowles, 2016; Larkin, 2017). This makes the learning to be able to connect and relevant to the students' experience, together with the complexity of the global situation. So, it can be suggested that how to use a robot for enhancing computational thinking skills. With the abilities to attract and encourage the students' learning process engagement of the robot, it is resulting in hands-on and self-directed learning by touching and manipulating the robot directly (Cheng, et al., 2017; Ziaeefard, Miller, Rastgaar, & Mahmoudian, 2017). Many studies proposed the benefit of an educational robot able to motivate students' learning with authentic learning activities based on real-world problems (Julià & Antolí, 2019) and to improve the students' confidence and skills related to abstract nature and advanced mathematics needed to understand the topic (Wu, de Vries, & Dunsworth, 2018). Using a robot in education not only employ inside and outside the classroom but also employ in meaningful learning activities for student as well. Some study proposed the robot workshop for high-school students have the opportunity to engage three-day workshop for who interesting science and technology are becoming the engineering students (Chookaew et al., 2018).

### 2.2 Learning approach

The importance to adapt the learning cycle approach to drive learning activity is widely recognized. The learning cycle approach is an educational strategy or technique that encourages students to discover or construct information by themselves, instead of having teachers directly provide the information through a scientific process (Duran & Duran, 2004; Pedaste et al., 2015). Learning cycle processes are able to improve students' achievement relative to scientific practices and increasing students' conceptual knowledge (Marshall, et al., 2017). The 5E instructional learning cycle is contemporary 5 learning-phases consisting of engagement, exploration, explanation, elaboration, and evaluation that are the most effective way of engaging students (Bybee, 2014). In the engagement phase, the students are asked to make connections between past and present learning experiences and organize their thinking toward the learning. The exploration phase is used to encourage students to explore questions and possibilities, and design and conduct a preliminary investigation followed by the explanation phase. The students are asked to explain their understanding of the concept. In the elaboration phase, the students are provided an opportunity to apply their understanding of the concept by conducting additional activities. Additionally, they evaluate themselves about the learning progress whether they have achieved the educational objectives.

### 2.3 Computational Thinking

The computational thinking basis concept of mathematics educations research (Papert, 1996). After that, computational thinking was described by many researchers in many times and worldwide. In the last twenty years, computational thinking becomes to a fundamental skill for everyone in every field, not just for computer scientists, especially for students in 21st-century skills that should have analytical

ability and reading, writing, and arithmetic process systematically (Wing, 2006, 2008). According to the finding of many studies confirmed that computational thinking is the conceptual foundation required to solve problems effectively (Shute et al., 2017). Based on the core concepts of computational thinking proposed by Wing, 2008 include decomposition, pattern recognition, abstractions, and algorithm design. In addition, computational thinking components are classified into three dimensions include computational concepts (the concepts that students employ), computational practices, (problem-solving practices that occur), and computational perspectives (the students' understandings of themselves) (Brennan & Resnick, 2012).

In this study, learning strategy is an empirically learning process for driving the robot activity consisting of engagement, exploration, explanation, execution, and evaluation. According to measuring students' computational thinking is a complicated but necessary task for understanding the effectiveness of robot activities. Our investigation focused on the implications of claims about students' computational thinking three dimensions consisting of *Computational thinking concepts:* the concepts that students employ to learn and understand during activities, *Computational thinking practices:* problem-solving practices that occur in the learning process, and *Computational thinking perspectives:* students' understandings of themselves, the relationships between team members.

## 3. Methodology

### 3.1 5E Robot-based Activities

Usually, commercial educational robot kits are used as learning tools in learning activates during the curriculums in the classroom or during learning activity in workshops, nevertheless, teachers frequently need to adapt the robot kits for specific learning objectives. Besides, commercially available robot kits are often expensive and are not easy to modify for learning activities. In this study, we developed robot kits called MEC-Ed (Mechatronic Education robot) that are low-cost robots prototype. The robots have been designed that can be built in many different forms. Each part of the robot was printed with a 3-dimensional printer or 3D printer. Also, the MEC-Ed robot is consist of many sensors to detect the task in scenarios, those sensors are ultrasonic (used measures the distance to an object with ultrasonic sound waves), line follower (used follow white or black lines), IR flame (used detect the presence of fire or other infrared sources), and RGB color sensor (used for detecting primary colors namely red, green and blue). The MEC-Ed robot kit can be controlled by the Scratch programming environment. The program is a drag-and-drop block for writing commands of the robot to operate with the mBlock program which is a freeware program that can be used to control the Arduino board. The MEC-Ed robots are introduced as learning material to employ engineering design as a motivator to teach STEM education.

In this work, the authors have revised the original 5E of phase 3 to make it to be more appropriate with robot activities named "Execution" instead of "Elaboration"

- *Engagement phase:* The instructor encourages the students' experience with the real world. Asking a question, defining a problem or task in order to motivate students to engage the learning activity. They are able to take what they have learned from the scenario with the mission activities.
- *Exploration phase:* The students explore and plan an idea to solve the problem or mission. They are able to think about what they have discovered from the scenario.
- *Explanation phase:* This phase provides the students with the common use of terms relative to the missions. The students explain the solution to solve a problem using common scientific terms. The student presents the methods about the control robot and justifies the approach to solving the problem in order to carry out the mission.
- *Execution phase:* The students execute the robot mission with a challenge. They are able to operate the solution through the activities to mission success. At this moment, the student employs systematic thinking with different problems upon their robot's settings and programming.

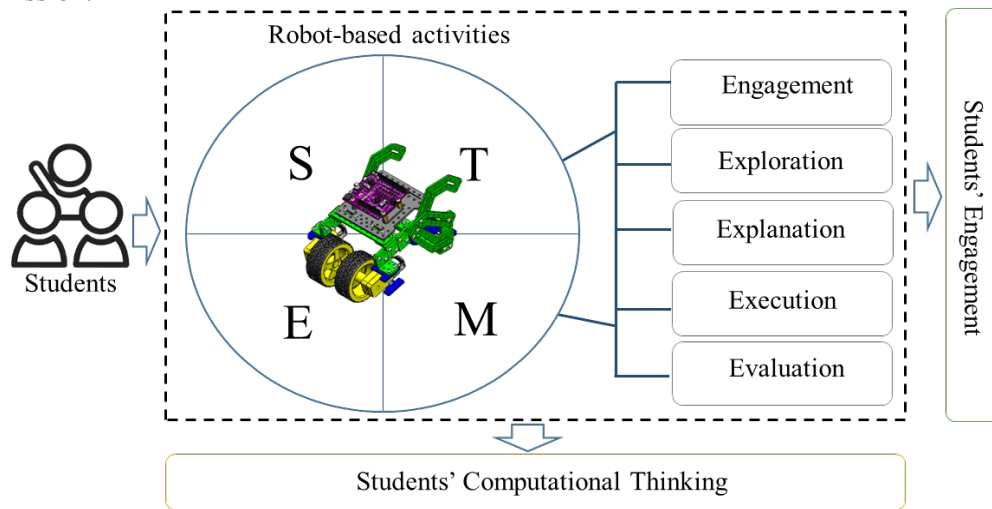- *Evaluation phase:* the students' mission outcomes are evaluated with the criteria for each mission.



*Figure 1.* Robot-based activities framework

As shown in Figure. 1, the elements of robot-based activities framework for learning in STEM (Science, Technology, Engineering, and Mathematics) were strategically embedded in learning activities with 5E instructional learning model to support students' computational thinking and engagement.

### 3.2 Participants

The participants were 29 high school students (18 males and 11 females) who are willing to participate in our research. The students ranged from 16 to 18 years of age.

### 3.3 Experiment design

The participants were divided into groups (3-4 participants per group) were formed to undertake with ask the students to form a line. They should line up alphabetically by given name then count off in groups 1, 2, 3 then and continue until all groups are formed. Every group has a mentor during activities for advising and facilitating the learning process in this activity. The robot learning activity was completed in three days (7 hours per day total of 21 hours). In research method the students followed the five stages of robot activity process are detailed as follows:
- Stage 1 (Engagement): Begins the first step addresses motivation to student-related components and functions of the robot and basic programming to control a robot. The students were introduced to the concepts of robot activities including assemble a robot, program robot movement, and learning the sensors.
- Stage 2 (Exploration): This step addresses the mission for solving a problem. The students have perceived the situation and engage the activity with the team to explore the problems. After that, they identified the problem and asking the questions with the robot missions.
- Stage 3 (Explanation): When the students know the problem based on their missions. They explained the solution to solve problems and plan or design activity in the next section.
- Stage 4 (Execution): In this step, the students attempted to execute the robot mission and the robot competition. They have hand-on activities for the competition.
- Stage 5 (Evaluation): In the last, the students' mission outcomes were evaluated. In addition, the students were assessed computational thinking during joint learning activity.
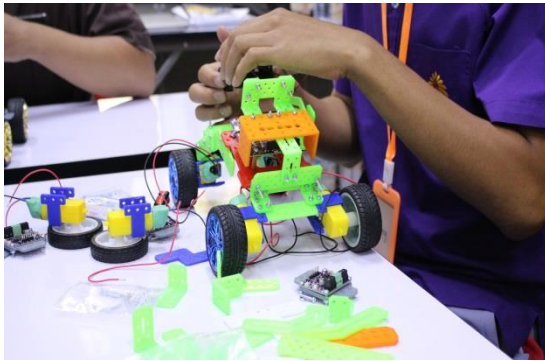
|   (a)  the robot assembly   |   (b) the robot missions   |

*Figure 2* Illustrative examples of robot learning activities

## 4. Results

### 4.1 The results in terms of the students' computational thinking

The items in this observation checklist were developed to the three dimensions of computational thinking that cover all concepts of the robot activities including 14 items: computational concept (4 items), computational practices (5 items), and computational perspectives (4 items). This checklist, the mentors have given the students rated each item on a five-point Likert scale (1 = Failed, 2 = Passed, 3 = Acceptable, 4 = Good, 5 = Excellent). This scale established expert validity through evaluated by five professors of educational robotics with more than 7 years of experience. The internal consistency for the overall scale was 0.82.

Table 1. *Means and SDs of the students' Computational thinking*

| Dimension items | Mean | S.D. | Remark |
|---|---|---|---|
| *Computational Concept (CC)* | *4.24* | *0.66* | *Good* |
| 1. Explanting the function of sensors | 4.10 | 0.66 | Good |
| 2. Modifying the robot follows the mission with scientific and mathematical concepts | 4.28 | 0.69 | Good |
| 3. Programming the robot motion for the missions. | 4.38 | 0.61 | Good |
| 4. Identifying the barriers that influence to the missions. | 4.21 | 0.66 | Good |
| *Computational Practices (CP)* | *4.14* | *0.78* | *Good* |
| 5. Planning the systematic problem-solving | 4.03 | 0.61 | Good |
| 6. Applying the sensors to complete the missions. | 4.48 | 0.81 | Good |
| 7. Controlling the robot to complete the missions. | 4.28 | 0.78 | Good |
| 8. Solving the problems related to the robot motion. | 4.38 | 0.72 | Good |
| 9. Operating the missions with confidence and accuracy | 3.72 | 0.69 | Acceptable |
| 10. Performing an independent work with confidence | 3.93 | 0.74 | Acceptable |
| Computational Perspectives (CPP) | *4.09* | *0.60* | *Good* |
| 11. Explaining the benefit of robot activity. | 4.14 | 0.57 | Good |
| 12. Connecting between the mission and the real-life situation | 4.34 | 0.48 | Good |
| 13. Applying scientific knowledge to solve the problem | 4.03 | 0.72 | Good |
| 14. Adapting the activity into the real-life situation | 3.86 | 0.51 | Acceptable |

As shown in Table 1, the students' computational concept were at good level (M= 4.24, S.D. = 0.66), practices and perspectives M= 4.14 (S.D. = 0.78), and M= 4.09 (S.D. = 0.60), respectively.

*4.2 The results in terms of students' engagements*

The items in this engagement questionnaire were adopted a revised version (Hutamarn et al., 2017) three dimensions of students' engagements after attending the robot learning activity that consisted of 11 items to assess behavioral engagement (3 items), cognitive engagement (4 items), and emotional engagement (4 items), while the latter examines students' satisfaction on 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = agree, 5 = Strongly Agree) The internal consistency for the overall scale was 0.79.

Table 2. *Means and SDs of the students' engagement toward robot inquiry-based learning activates*

| Questionnaire items | Mean | S.D. | Remark |
|---|---|---|---|
| *Behavioral Engagement* | *4.53* | *0.54* | *Strongly Agree* |
| Q1. I can participate and work in a group activity. | 4.62 | 0.49 | Strongly Agree |
| Q2. I attempt to define and discuss the missions. | 4.48 | 0.56 | Agree |
| Q3. I think an environment not a barrier to my learning. | 4.48 | 0.56 | Agree |
| *Cognitive Engagement* | *4.40* | *0.61* | *Agree* |
| Q4. I think robot activity improves my thinking process and work. | 4.52 | 0.50 | Strongly Agree |
| Q5. When I am not sure something, I always consult a mentor. | 4.69 | 0.53 | Strongly Agree |
| Q6. When the problem occurs, I attempt to find the solution myself. | 4.10 | 0.66 | Agree |
| Q7. I always plan before I operate in an activity. | 4.28 | 0.52 | Agree |
| *Emotional Engagement* | *4.49* | *0.58* | *Agree* |
| Q8. I think I can apply the robot activity in my life. | 4.38 | 0.61 | Agree |
| Q9. I feel that robot activity is a challenge for me. | 4.52 | 0.62 | Strongly Agree |
| Q10. I prefer robot activity. | 4.69 | 0.46 | Strongly Agree |
| Q11. I think robot activity not only makes me have knowledge but also have fun as well. | 4.66 | 0.48 | Strongly Agree |

As shown in Table 2, in the students' behavioral engagement dimension the students were strongly agree (M= 4.24, S.D. = 0.66) while the students' emotional engagement dimension were agree (M= 4.40, S.D. = 0.61), and the students' cognitive engagement dimension were agree (M= 4.49, S.D. = 0.58), respectively.

## 5. Conclusions

In this article, the authors attempt to propose the robot inquiry-based learning activates to foster students' computational thinking. For the development of educational, the robot called MEC-Ed robot kits that can support students' computational thinking through a learning approach to drive activity with missions. The results demonstrate that the students' three dimensions (behavioral, cognitive, and emotional engagement) of engagement are at a high level.

The educational robot activity is particularly effective in delivering the contents of difficult disciplines for learning, it can re-establish a balance between the student and the technological material because the student can learn and develop computational thinking skills as well.

This can significantly boost the learning environment more completely; in the meantime, they can naturally understand the learning phenomena both positive and negative in order to improve later. Research finding, it has a generalization issue due to the implementation of one sample group. In the

future, a comparison study between groups of samples, experiments, or interventions can enhance the impact of this finding.

The advantages of the educational robot that integrate with the learning approach to enhanced student thinking are presented here. In particular, in the future work, we should attempt to implement this MEC-ED robot in a real case study and then extend it to different realities because the student experience, the provincial and regional norms make a difference in the outcomes.

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