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Students' Computational Thinking Skill through Cooperative Learning Based on Hands-on, Inquiry-based, and Student-centric Learning Approaches

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Abstract Of late, computational thinking (CT) has received a great deal of attention from scholars and educators, given its immense potential in nurturing students' problem-solving skills, which are the type of skills highly needed in today's technology-driven era. For example, in Malaysia, a number of efforts have been pursued to develop strong computational thinking among school students through the implementation of learning activities that nurture such a skill in most of the school subjects. However, previous studies have shown that teachers have a low understanding and misconception about the concept of computational thinking, which could derail such efforts. Furthermore, the lack of studies focusing on motivating students to actively participate in the learning process is further compounding such a predicament. Premised on this context, this study was carried out to examine the impact of cooperative learning on the development of CT skill among a group of 25 Year-3 students, aged 9, which was carried out based on three learning approaches, namely student-centric, hands-on, and inquiry-based approaches. Through such learning, which took place at one private school located in Selangor, Malaysia, the students learned four learning concepts related to a topic of a science subject. In this study, the researcher played the role of a teacher by teaching these students the learning concepts using a lesson plan designed based on the three learning approaches. The methodology used to collect data was based on a class observation and an interview with the science teacher. The analysis of the qualitative data revealed that students were highly engaged and participative in the learning process and were able to learn the scientific concepts of the subject matter with greater efficacy, which was indicative of their improved CT skill. As such, these findings underscore the imperative of developing and nurturing computational thinking among students, with which students would be able to solve complex problems more effectively

Keywords Computational Thinking, Cooperative Learning, Hands-on Learning Approach, Inquiry-based Learning Approach, Learning Concepts, Problem Solving, Student-centric Approach

1. Introduction

Computational Thinking (CT) is one of the important skills that all individuals must have for problem-solving and decision-making through a systematic approach. In fact, the emphasis on such a skill has been raised several decades ago, suggesting its strong relevancy in people's daily lives, in which problems of sorts abound. As with many other types of skills, the best way to introduce CT is via education by embedding relevant learning activities into existing curricula, especially at the early ages.

Of late, many scholars and practitioners have raised the imperative of having a well-developed CT skill among students. In this regard, [1] assert that students in this century need to possess sound CT skill in dealing with more challenging problems compared to those in earlier centuries. In other words, the imperative for such a skill has grown significantly, given the complexities of today's life. Likewise, computational thinking has been described as an essential skill, which everyone should acquire in addition to other types of skills, thus enriching his or her set of skills [2]. Similarly, [3] affirms that computational thinking is the universal competence, which should be added to every child's analytical ability as a vital ingredient of their school learning. In line with such affirmation, [4] contends that every child should possess computational thinking, entailing teachers and instructors to undertake more serious efforts in developing such a skill. In fact, the last decade has witnessed such efforts that have been put in place, and similar efforts have been gaining traction ever since. In recent years, the literature is replete with studies discussing the importance of adding computational thinking to the existing set of skills, treating it as a core ability that every child must have [5].

Decision-making and problem-solving are not synonymous, but such abilities are highly related. Among the two, problem-solving is considered as a fundamental human skill [6]. In principle, the decision-making process involves the identification and resolution of problems [7]. As such, as emphasized by [8], computational thinking is a skill that students should possess in order to develop a sound problem-solving skill using principles derived from computer science. Those principles include decomposition, algorithm, pattern recognition, abstraction, evaluation, logical reasoning and many more. Given that computational thinking augments the problem-solving process, such a skill could be introduced using words that describe or define problems [5]. Furthermore, computational thinking has the potential to advance students' problem-solving skills and abilities significantly, with which they could think in new ways[9].

Over the past decade, computational thinking has become a very hot topic in educational research and practice [10]. For example, the research by [2] showed the number of studies focusing on computational thinking has been growing steadily in many different educational contexts across the world; nevertheless, they assert that specific work relating to computational thinking is still in its infancy. A similar assertion is echoed by [3] and[11], who contend that research on the integration of computational thinking in education is still limited. In response to the lack of such research, several researchers have begun to dedicate their studies to computational thinking involving students. For example, [12] carried out a study in which they found that CT scores correlated strongly with general academic success, thus they concluded that such a skill could be used as an early indicator and predictor of academic success. Spurred by the promising, interesting findings of a study by [1], new methods and techniques for integrating CT into existing curricula have been proposed to help students develop CT skill, encompassing all levels of education, from the pre-school to the university. In particular, they suggested that several activities could be developed and applied to public schools for students of different ages. Through such activities, teachers could teach their students to solve problems in a systematic manner that help improve students' CT skills.

Thus far, a majority of countries are still in the process of implementing CT-based learning activities in the classroom [2]. Remarkably, the Malaysian government has taken several efforts on computational thinking implementation in schools by training teachers on how to apply computational thinking to the school subjects from primary to secondary schools. Notably, in 2016, the Ministry of Education of Malaysia announced that computer science and computational thinking would be introduced to the national education curriculum starting January 2017 involving students of Year One, Form-One and Form-Four levels [13,14]. As emphatically emphasized by [13] Karamjit Singh (2016), such a bold move was not surprising in view of the fact that, lately, computational thinking is viewed as a catalyst for transforming the Malaysian students from digital users to digital creators.

He further asserts that the real focus of computational thinking is not on IT skills but on the thinking skills required in solving complex problems. In this regard, the Malaysian Digital Economic Corporation (MDEC) has been working in tandem with the Ministry of Education of Malaysia in incorporating computational thinking and computer science into the national school syllabus [15]. It is therefore hardly surprising to note that such an initiative has been given a high priority, as all the major stakeholders have begun to realize the need to develop higher order thinking skills among students for science, technology, engineering, and mathematics (STEM) education. Undeniably, CT skill and STEM education are tightly interwoven, such that the lack of the former would have an adverse impact on the latter [14]. In fact, such a relationship has been recognized to be important by many scholars and educators, made evidently clear by the increasing emphasis on STEM education and its computational counterpart [16]. Furthermore, [16] quoted [17-19] Henderson et al. 2007) which state the primary motivation for introducing CT practices into the teaching of science and mathematics is attributed to the rapidly changing nature of these disciplines, as witnessed in the professional world

Admittedly, the implementation of computational thinking in teaching is not an easy task. For example, a study carried out by [20] showed that, in general, a majority of teachers in Malaysia had a low understanding of computational thinking. More revealingly, these teachers perceived computational thinking as some sort of skill related to the use of computers or ICT devices in the classroom. In other words, very few of the teachers had a correct understanding of such a skill that involves the thought process required for problem-solving. Put simply, they might have construed CT skill as programming skills. Arguably, such a belief stems from the influence of research findings pertaining to programming skills required for software and programming languages such as scratch [21] and robotic [22]. Likewise, [23] stated that most of the studies merely focused on the training of programming skills and mathematical computing, with a handful adopting a cross-domain teaching mode to enable students to manage and analyze the materials of various domains by computing. In this respect, [24] assert that the process of helping students to develop sound computational thinking in schools would be complex, requiring a systemic change, intense teacher engagement, and the development of appropriate resources.

Clearly, the successful implementation of CT training would entail a combination of approaches, such as student-centric, hands-on, and inquiry-based approaches. Additionally, cooperative learning could be fostered through the CT training in the classroom. According to [25], cooperative learning is a pedagogical practice that has attracted much attention over the last three decades, as a large body of research has indicated that students would be able to gain several benefits, both academically and socially, when they are given the opportunities to interact with one another to accomplish a number of shared goals. Specifically, the benefits that the students could reap include their ability to share ideas, clarify differences, construct new understandings, explain new experiences, demonstrate a more sophisticated level of discourse, engage in discourses with fewer interruptions when others speak, and provide more intellectually valuable contributions. From the teaching perspective, [4] asserts that, in general, teaching strategies could be divided into two main types, namely teacher-centered and student-centered learning strategies. Between the two, implementing the latter would be more challenging as teachers need to scrutinize students' activities at the individual level more closely. Furthermore, [26] argues that teaching is a complex, ongoing endeavor that involves a myriad of decisions. This is particularly true for student-centered learning, where students would be responsible for finding reasons that they could use to create knowledge and understanding [27]. To this end, there are various CT concepts that could be implemented in the classroom, such as logic, algorithm, decomposition, pattern, abstraction, and evaluation [28]. However, not all of the concepts need to be applied in one lesson.

Against the backdrop of issues highlighted above, this study was carried out to demonstrate how computational thinking could be incorporated in the classroom using such concepts. More specifically, the main aim of this study was to investigate whether the implementation of CT learning based on the student-centric, hands-on, and inquiry-based approaches would be able to motivate students to participate actively in the classroom. The context of this study was on the learning of a science subject involving a group of Year-Three students, whose mean age was 9 years old. By actively participating in such a learning process, students were expected to gain a greater understanding of the contents of the subject matter.

2. Methodology

The sample of this study consisted of 25 Year-Three pupils of a private primary school located in the state of Selangor, Malaysia. The selection of year 3's pupils whose age is 9 was made based on the fact that CT need to be introduced at the early ages, and year 3 is at level 1 of primary school. More specifically, the investigation took place in Class 3 Bukhari on 8th. March 2018. The learning session lasted for one hour, starting at 10.30 am and terminating at 11.30 am. The researcher played the role of a teacher throughout the learning session. After the completion of the learning lesson, an interview with the science teacher was carried out. In the teaching and learning process, a lesson plan serves as an important tool to guide teachers in delivering and explaining the learning contents and concepts. Thus, an appropriate lesson plan to guide the science teacher was prepared based on the Curriculum Standard Document and Assesment (DSKP) for the Year-3 Science subject. The selection of topic 3, Animal feeding habits with the subtopic "Express animal eating habits: herbivores, carnivores, omnivores" was chosen because the topic was scheduled to be taught in that particular week proposed by the researcher. The video was taken to record the session to be evaluated. Three pictures of the three types of animals (tiger.jpeg, goat.jpeg, hen.jpeg), a video of animals (Animals Atlas of Africa.mp4), individual worksheet (exercise.doc) and A4 paper for group discussion were prepared accordingly.

3. Finding and Discussion

This section discusses the three main aspects of the cooperative learning of the selected topic of the science subject. The first aspect centered on the teaching & learning implementation, followed by the second aspect focusing on students' participation and motivation, and finally the third aspect was concerned with their understanding of the learning content. The class started with the teacher asking the students about what they had done during the recess time. In response, the students gave various answers, among which a majority were related to that they had taken for during recess. Then, the teacher asked the reasons why they chose a particular type of food. Four students indicated that they needed to take such food for a number of reasons, such as to gain energy, help them grow healthy, and overcome hunger, and they also indicated that all living things need food to survive. Based on these answers, the teacher concluded that every living animal needs to eat for the same reasons, notably to sustain its life. As observed during the introduction activity, only a handful of the students participated in by providing answers, all of which were correct. Clearly, the logical reasoning of concepts plays an important role in arriving at such a conclusion.

When the learning session migrated to the learning contents, more students were involved by asking and answering questions. Learning the contents involved three steps to help guide the students, with each step being performed with a series of questions. Surprisingly, one student gave a wrong answer to a question about the type of food that tigers eat. In fact, the student mentioned grass, not other small animals. Arguably, this student might have been confused by a picture showing a tiger laying on a swathe of grass, thus making him infer that grass is the basic food for tigers. In such a case, the teacher had to emphasize that the words "eat" and "eating habit" were different based on a habitat. Eventually, more answers were given by other students, such as deer, meat, goat, rabbit, horse, buffalo, mousedeer, and humans, among others. To respond to the question, students were required to write their answers on a whiteboard. In this learning session, the teacher took every measure to ensure all students would get involved by giving them ample opportunities to think over the answers to such a question, culminating in a list of answers written on the whiteboard. For the second step of the learning session, an inquiry-based approach was used, with the teacher asking the class if the above list could be classified under one category or term. Interestingly, one male student managed to classify the list correctly, stating that the answers fall into the category of animals. Apparently, this student used the abstraction of concepts to help him see a pattern emerging from the list, indicating a theme of animals. Later, the students were asked the same question: What do tigers eat? At this time, all the students managed to answer correctly by stating that tigers eat other animals. Emphatically, the teacher responded that their answer was correct and that the term used to describe the type of animals that eat other animals (meat) was carnivores. For the third step, the teacher posed a probing question to the students as follows: What are other animals that have the same eating habit as that of the tiger? As expected, the students gave numerous answers, some of which were correct, whilst others incorrect. Some of the correct answers given by the students were lion, cheetah, rhinoceros, crocodile, python, and bear. Together with the teacher, the students checked the list and confirmed whether the animals listed were in the same group. For incorrect answers, the teacher and students had to discuss the reasons why such answers were wrong, with the former asking the latter the type of food that such animals eat. In particular, the teacher explained that certain animals eat different food compared to that of the tiger. Furthermore, the teacher emphasized the particular concepts by asking further questions, such as "Which of the listed animals have the same feeding habit as that of the tiger?" and "What do you call the animal that eats other animals?" to which all the students were able to answer correctly by stating that the animal was a carnivore. All the three steps were repeated for the other two kinds of animals, namely a goat and a hen, to represent a herbivore and an omnivore, respectively. When the students were shown a picture of a goat and asked about the food that this animal eats, some students gave a simple answer, which was the grass. Then, when urged further by the teacher, the students gave more answers, such as tree leaves and weeds. Later, the teacher asked the students to generalize their answers, to which they were able to do so by stating that the above answers could be referred to as a plant. Repeating the same interrogation using a hen as an example, the students answered that this poultry animal ate worm and rice. Interestingly, one female student managed to give the most precise answer, stating that the types of food that hen fed on were plant and animal. Obviously, it seemed that this bright student had already known the concept of generalization, given her generalized answer. When the teacher asked about other animals that had the same eating habit, the students' answers were duck, bird, hen, and rooster. Finally, the teacher emphasized the term "omnivore" to represent animals that eat both plant and animal.

As revealed in this study, questions that had more than one answer were able to make students more engaged and engrossed in the learning activities. For example, the question pertaining to the types of food that tigers, goats, and hens eat elicited an almost limitless number of answers. Furthermore, based on the list of all types of food (eaten by these three animals), some students were able to classify tigers as carnivores that ate animals, goats as herbivores that eat plants, and hens as omnivores that ate both animals and plants. Clearly, at this stage, the abstraction of concepts through generalization was introduced to the students. As such, this abstraction helped the students to identify the general principles that highlighted a certain pattern. Put simply, the abstraction of related concepts was derived from such a pattern.

For the second step of the learning process, the question asked centered on other animals with other eating habits. Again, such questions generated a variety of answers, to which the teacher did not say whether they were correct or wrong. Instead, the teacher listed their answers on the whiteboard, which were then scrutinized critically to determine the correct type of food that each animal feed on. Effectively, the teacher introduced the logical reasoning of concepts, which in this case involved classifying one type of animal under a certain group. As such, the students, together with their teacher, deliberated on the type of food eaten by the animals listed on the whiteboard and subsequently confirmed the category of each animal according to their eating habit. In this regard, another CT concept was introduced, namely the evaluation. In addition, the pattern recognition concept was introduced to the students by asking them to observe the patterns, trends, and regularities of these animals' eating habits. To recognize such patterns, the students had to recall their previous knowledge of the type of food consumed by such animals. To answer the questions in the first and second steps of the learning process, the students were prompted with some keywords, such as eating habit, animal, and plant.

Moreover, the teacher emphasized that these animals could be categorized into three types of animals based on their eating habits, namely herbivore, carnivore, and omnivore. In answering the questions, students' tacit knowledge of the type of food that these animals eat was linked to the students' explicit knowledge of the animals' eating habit.

Prior to the enrichment activity, the teacher explained that animals could be classified into three categories, namely herbivore, carnivore, and omnivore, depending on the similarities and differences in the animals' eating habits. To help students learn such a concept, a video entitled "Animals Atlas of Africa" was played, showing many different types of animals that live in Africa. While watching the video, students in a group of three were asked to classify such animals shown in the video into three type of categories, namely herbivore, omnivore, and carnivore, based on the eating habits of the animals. In the enrichment activity, students (in a group of three) were given ample opportunities to discuss with one another. To facilitate such discussion, all the eight groups of students drew three columns on the A4 paper, on which the category and eating habit of each animal were written. However, watching the video proved to be a daunting task, as the playback of the animals was too fast to allow the students enough time to discern the category of each animal. Arguably, a workaround to overcome such a shortcoming was to let the students list down the animals that they saw in the video first and then let them decide the category of the animal after the end of the video. As anticipated, some students had to struggle to complete the enrichment task, as they were not familiar with some of the animals that appeared in the video. Naturally, they had to refer to the teacher to know more about such animals. Additionally, they were asked to find more information about the animals after class, such as the eating habits of such animals.

Through this cooperative learning activity, it was observed that several students were seen to be more dominant than the rest of the group members, which might be detrimental to the learning process involving student groups with a larger number of students. Given that this study used student groups consisting of only three members, problems arising from students having different levels of engagement were minimized. Moreover, to ensure full participation of all group members, each student would be required to write his or her answer on a whiteboard in front of the class. In this way, no one would be left out and each student group could compare their answer with those of others, thus making the learning process more student-centric. In this respect, previous studies have shown that class participation is an important aspect of student learning. For example, when students speak up in the classroom, they learn to express their ideas in a way that others could understand. Furthermore, when they ask questions, they learn how to obtain information to enhance their own understanding of a topic [29]. Evidence found in the literature suggests that greater classroom participation could help motivate students, support their learning, improve their communication skill, and promote higher-order thinking skills [30]. It must also be emphasized that classroom participation is not only important for the communication between students and the teacher but also vital for the communication between students and their peers. With greater classroom participation, students could learn from each other and internalize their knowledge better [31]. [31] also asserts that students who are able to share their opinions in class discussions would feel rewarding from such experiences. Moreover, active participation in the class could also boost their morale and confidence. To gauge students' understanding of the learning contents, each student was instructed to write his or her answers on an answer sheet. As expected, there were some variations in their answers; however, as a whole, all the students managed to provide their answers with some good examples, which were obviously based on their discussion in the classroom. In addition, some students managed to define the terms or categories of animals correctly, while others merely wrote down simple nouns, such as plant, animal, and both animal and plant. Surprisingly, and promisingly, none of the students gave a wrong answer. Before ending the class, the teacher asked a volunteer to make a conclusion on what the students had learned, which the volunteer did confidently by relating the eating habits with the structure of animals' teeth, which would be taught in the next lesson.

A day after the class, an interview session was conducted with the science teacher. The teacher was asked about her students' participation in the class based on her observation, as she was also present in the class while the learning session took place. To this question, she expressed her satisfaction unequivocally, clearly signifying her approval of her students' level of engagement in the cooperative learning process. She also said that all the students were engaged throughout the lesson; however, she noticed that the levels of engagement among the students varied quite significantly. Therefore, she cautioned that close monitoring should be exercised more often to ensure all students would partake in the learning activities with the same degree of participation in the future. In general, the findings of this study suggest that through inquiry-based learning, using relevant, probing questions, students would be able to develop sound CT skill, the impact of which by fully engaged in learning the educational materials and contents. Furthermore, according to [32] (2017), there is a close link between engagement and learning. As such, relevant learning approaches should be used, such as inquiry-based learning; to make students become more active and, therefore, more engaged, in the learning process, which would lead to the development of strong CT skill required for problem solving.

4. Conclusions

As discussed previously, CT skill has been introduced in all primary and secondary schools in Malaysia with the aim to enhance problem-solving skills among students at the early age of learning. To date, a number of studies have been carried out to examine the impacts of CT skill on students' learning performance. However, few studies have been devoted to investigating its impact on students' motivation to participate actively in cooperative learning. As such, lack of research has prompted the researcher to conduct a study to examine such an impact. As acknowledged, CT skill is required to help solve a myriad of problems in various domains. In particular, students need to develop strong CT skill, with which they could use to solve complex problems more efficiently and accurately. In other words, with sound CT skill, students would be able to formulate quality solutions. In this regard, CT skill could be applied to a variety of problem-solving tasks in several school subjects, notably in science subjects or courses. However, developing such a skill will entail sound pedagogical learning approaches. As demonstrated in this study, three learning approaches, namely student-centric, inquiry-based, and hands-on learning approaches are effective in developing strong CT skill among young students. Through such learning approaches, students could become highly active and motivated, effectively making them more receptive to engaging in problem-solving activities, which lead to better CT skill.

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