Computational Thinking in STEM

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ABSTRACT

Computational Thinking (CT) plays an important role in education recently due to its capability to fit into the framework for 21st Century Learning to inculcate critical thinking, communication, collaboration, and creativity (4C) among students. As Malaysia moves toward producing creative innovators in the future rather than expert end-users, emphasizing Science, Technology, Engineering, and Mathematics (STEM) in current curriculum is critical to ensure the students learn and understand everything that revolves around them every day. Teaching approaches called project-based learning and flipped classroom become among popular approaches to ensure the students learn at their best. The question is how can we enhance the 4C skills through the teaching method while the students learning the subject? Due to the rapid development of gadgets and technologies, the education system enables to shift to another paradigm where subject domain, teaching methods and technologies will be merged to have an approach that aims to boost deep understanding and innovative mindset. By using the fundamental concept of computation itself, CT uses six main concepts namely decomposition, abstraction, evaluation, algorithm, pattern, and logical reasoning. These concepts will be applied in class through Brain-Inquiry-Computation Thinking (BIC) model. This paper presents the fundamental concepts of CT and how Pendidikan Islam subject for standard one of primary school can be taught using CT.

ABSTRAK

Pemikiran Komputasi memainkan peranan penting dalam pendidikan masa kini disebabkan oleh kebolehannya menempatkan diri ke dalam rangka-kerja Pembelajaran Abad ke-21 bagi mencungkik kemahiran berfikir secara kritis, komunikasi, kolaborasi, dan kreativiti (4K) di kalangan pelajar. Memandangkan Malaysia bergerak ke arah melahirkan pencipta yang kreatif pada masa akan datang berbanding dengan pengguna akhir mahir, penekanan kepada Science, Technology, Engineering, and Mathematics (STEM) di dalam kurikulum adalah kritikal bagi memastikan pelajar dapat belajar dan memahami apa sahaja di keliling mereka setiap hari. Pendekatan pengajaran yang dinamakan pembelajaran berasaskan projek dan flipped classroom menjadi antara pendekatan yang popular untuk memastikan pelajar belajar pada tahap yang tertinggi. Persoalannya ialah bagaimana boleh kita memperbaiki kemahiran 4K melalui kaedah pengajaran ketika pelajar mempelajari matapelajaran mereka?
Sharing Best Practices in STEM Mentor-Mentee


Keywords

Computational thinking, 21st century learning, pedagogy
(1) Introduction

21st century learning focuses on student centric by using technologies as a tool to enhance not only on the knowledge level but also critical thinking capability. With the current technologies, students enable to access knowledge anytime, anywhere. Therefore, techniques namely flipped classroom, project based learning, and blended learning are some examples focus on enhancing students capability to think critically and also promoting self learning for long life learning goal. Authors (Foldnes (2016), Isomottonen & Tirronen (2016), Kim & Ahn (2018), Zhang et al. (2016)) proved the use of flipped classroom technique gives benefit to the students in term of capability in giving insight, improving skills, and independency in functional programming, introduction to computer information systems, system modeling, statistics, and mathematics course. Project based learning technique has been used since year 1960s in variety of subjects starting from medical course. The technique enables not only inculcate critical thinking by solving a problem but also encourage teamwork and self-learning motivation. Due to the emergence and stability of Internet and technologies, mobile gadgets have also been used by students and educators to enhance the learning experience outside the classroom (Sung et al. (2016), Suárez et al. (2018), Zydney & Warner (2016)). Therefore, they use blended learning technique to not only to incorporate problem based learning in class but also using Internet to solve and gather more information of the subject taught. Because of that, Massive Open Online Courses (MOOCs) becomes an increasing attention since 2008 due to Internet availability in most of the part of the world and using collaborative learning method that gives an open courseware to students who wants to learn properly following syllabus provided by the university. These existing methods aim at giving students the content knowledge at their comfort anywhere around the world. Even though, the students achieve a great amount of knowledge, they also need to have the capability to solve problems using the technologies around them as they live with the technologies since they were born. However, with great amount of knowledge acquired by the students do not indicate the students’ capability to use the knowledge in solving problems.

Technology is everywhere around us from the moment we wake up until we go to sleep, from e-alarm system which we can snooze and give variety of sound for every single day until an app that reminds us to sleep so that we can get better sleep with lullaby sound to soothe the ambience of our room. Therefore, a comprehensive and significant method in teaching is needed to embed technology and inculcate the students’ critical thinking at the same time. The current teaching methods lack of problem solving method in a concrete way. By using the method on how the computer works, the students are guided properly in solving any problems. Since the computers use many methods to problem solving, the students will have many options that increase their creativity skill.

(2) Computational Thinking

Computational thinking becomes popular since Jeannette M. Wing published a paper about it in ACM Communications magazine back in year 2006. According to (Wing, (2006)), computational thinking involves solving problems, designing systems, and understanding
human behavior by using heuristics reasoning to discover a solution. It is parallel processing, abstraction, decomposition, to prevent, protect, and recover from worst case scenarios through redundancy, damage containment, and error correction. She stressed out that thinking like a computer is not meant for computer scientist only but also to everybody. By using computational thinking, we will familiar with algorithm, parallel thinking method. Fundamentally, there is six major concepts in computational thinking.

1. Decomposition

A process by which information, processes, or problems to be broken into smaller, manageable parts. For example, there is a problem of traffic jam in most major city in Malaysia. The problem can be decomposed into the size of the road, number of the vehicles, and time of the traffic jam. Each sub problem will be solved based on its requirements.

2. Pattern

A process to find regularity and trend in collected data. For example, there is a problem to increase sales by a salesman. The salesman can look at the pattern of its sales record in term of when most customers and when less customers bought the product. He also can look at what kind of products the customers prefer to buy and on which holiday season.

3. Abstraction

A process to remove details to extract only relevant idea in order to define main idea(s). For example, a student has to present about a hundred pictures of living things he had given by the teacher. In order to ensure his presentation can easily be understood by his friends in class, he organizes the picture based on human, flora and fauna. Then, he will explain with the pictures given based on the categories he decided to use.

4. Algorithm

A process or set of rules to be followed in a series of instructions or other problem-solving operations. For example, a guy attended a conference gets lost while looking for a restroom. The helpdesk man will give him a series of instruction to go to the restroom.

5. Logical Reasoning

A process to explain and justify on how the algorithms work, to detect and correct errors, and to predict the outcome of the algorithms. For example, to ensure the class party well-managed and fun, the class monitor will list down of all steps taken and all the possibilities that can happen during the party. He explains the plan to his teacher and explain why it will work perfectly.
6. Evaluation

A process to ensure the proposed algorithm, system, or process as a solution fit the purpose. For example, by using the same example as in Algorithm, the helpdesk man suggested another route to the restroom which he claimed shortest from the previous one he mentioned. So, the helpdesk man explain to the guy why the second route he suggested is shortest even though it sounds complicated. However, the guy chose the first suggestion as it is fit the purpose of him going to the restroom and sounds less complicated.

(3) Computational Thinking in Teaching

Those who have no concrete understanding of CT would assume that it is directly related to the understanding and teaching of STEM subjects. This is not entirely true. CT skills are very much encouraged and even necessary in the teaching of subjects like STEM due to the nature of these subjects which are similar to the concepts of CT. According to Burbaitė (2018), in science practices, mathematical and computational way of thinking are essential in making predictions, testing theories, and finding patterns or correlations between variables. Even so, CT is not to be used only for STEM subjects but can also be applied across other subject areas.

3.1 The BIC Model

On its own, CT can be incorporated when teaching students in Malaysian schools. Teachers would be able to teach a topic while implementing CT practices and concepts to help the students grasp the knowledge. However, for this skill to effectively benefit the students, it must be incorporated within a structured, teaching approach. Cheah Hew Mee (2018), created the BIC model to successfully integrated CT skills into a pedagogy. She tested this model on 88 teachers across Malaysia and 91% of the teachers changed their teacher-centric approach to learner-centric. Furthermore, these teachers were more creative in their content delivery due to this model.

BIC model stands for “Brain based-Inquiry based-Computational Thinking” model. According to Chew (2018), the BIC model will increase educators’ confidence in applying the computational process into teaching and recognizing how algorithms can articulate a process or rule. Brain-based makes up the structure of the teaching plan, inquiry based is the teaching approach used, and computational thinking is the skill embedded into this teaching/learning pedagogy.

3.2 Teaching Structure : Brain-based

The Brain-Based Teaching Approach (BBTA) is based on the Brain-Based Learning Principles (Saleh, 2012). This principle consists of seven main steps where detailed attention is given to each one.
i. Activation
This section of the teaching process uses student’s existing knowledge to introduce the new knowledge. This is to help them relate the current topic with previous knowledge and to better understand the scope of a problem.

ii. Develop
Here the teacher facilitates the assimilation and integration process of prior knowledge and new knowledge. The students’ ability to connect what they already know to the new information determines how they learn and apply this knowledge.

iii. Practice (Learn by doing)
Skills or knowledge which are underdeveloped should be practised and teachers will facilitate this activity by prompting them and giving proper and timely feedback.

iv. Integration (Mastery of skills)
Students should be given the opportunity to continue practising their newly acquired skills until they master those skills and are able to perform them fluently.

v. Review
This section is where the teacher will reiterate what has been covered in the lesson and students will summarize what they have learnt. This should help in the retention of this newly acquired knowledge or skill.

vi. Preview
The teacher will make a connection with the current knowledge with the upcoming lesson. This preview will give students a chance to pre-process the information before the next class and also reinforce the current knowledge to memory.

3.3 Teaching Approach: Inquiry-Based

Inquiry-Based Learning (IBL) was established by John Dewey and it was built on the belief that students should be taught how to think and act instead of memorizing facts and accepting them at face value (Lazonder, 2016).

A study carried out by Abdi (2014) showed that students who went through IBL obtained a higher score in the post test as compared to those who went through the traditional learning method. Another study carried on IBL showed a significant increase in interest on the subject when conducted on a science and technology lesson in school (Potvin, 2017). Based on these and several other findings, IBL is said to give positive impact on a student’s interest and learning ability of a topic. This approach was chosen by Chew (2018) to be implemented in her BIC model. IBL emphasizes on the student’s ability to carry out independent learning where teachers act as a facilitator to point them into the right direction. Research suggests that IBL is able to produce students who are creative, confident, and independent (Kuhne, 1995).
Referring to Figure 1, it can be said that the Inquiry-Based Process Cycle is made up of activities that are student centered. It is evident that teachers take a back seat in this learning method and act mostly as a facilitator. An example of the IBL in practice is where a student would be presented with a problem by the teacher. The student would then study the problem this should prompt him to ask question to get further information or clarification to the problem. The next step would entail the student to investigate and record the findings of the investigation. The information he discovered will be examined and interpreted and following that he will analyse and discuss the information to find alternative explanation to it. After that, he should try and experiment with the knowledge he obtained to see whether the result could be repeated. Finally, he will revise the new knowledge and try to revise or improvise on it before he concludes it.

Inquiry Based Learning was chosen for the BIC model because it builds lifelong skills that are needed by students. Students would also learn to cope with problems, deal with changes and challenges to understanding. It encourages them to search for solutions and develop their problem solving and lifelong learning.

3.4 The Skill: Computational Thinking

CT skills will be incorporated into the teaching of the subject in this BIC model due to its many benefits as discussed in previous sections.
3.5 BIC Conceptual Framework

Based on the description given in this section, the complete BIC model and all its parts can be illustrated using Figure 2.

![BIC model conceptual framework](image)

Figure 2: BIC model conceptual framework

As shown above, the model ensures that the teaching process is delivered using the Brain-based structure and goes through the 6 stages. Within those stages the 7 IBL processes will be used as the approach to learning. Not forgetting that CT skills are used to facilitate efficient learning by the students.

(4) Example of Computational Thinking implementation in current syllabus

As discussed in the previous section, to implement Computational Thinking (CT), it is recommended to conduct the class through BIC model explained before to enable the CT concept being implemented more efficient. There should be a combination of any six CT concept that has been introduced. These CT concepts are not necessarily done sequentially, they can be done according to the suitability of the activities prepared by the teacher. Also, keep in mind, the implementation of CT into the syllabus of learning is not limited to science and mathematical subjects alone. It can be used across all subjects including Bahasa Malaysia, Music, History, Islamic education, Arabic language and more. For example, in this chapter we introduced how CT can be incorporated into the Islamic education subject for first year primary school student. Table 1 below shows how existing teaching methods are carried out. And Table 2 shows how can we improved the teaching method through our proposed method.

<table>
<thead>
<tr>
<th>Table 1: Current approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>Year</td>
</tr>
</tbody>
</table>


**Topic** | Memorizing and Reading Surah Al Fatihah with the correct Tajwid
--- | ---
**Approach** | Current method

**Activity**
1. Pupils are divided into groups (4 students for each group)
2. Each group is given a set of flash card in a form of puzzle containing surah Al Fatihah (Figure 1)
3. Each group has to rearrange the flash cards to form the correct order of Al Fatihah sentence.
4. One representative from each group will be asked to read their findings based on the pre-arranged words.
5. The teacher will listen and correct the arrangement of the sentences and pronunciation if necessary.

**Teaching Materials**
![Sample flash cards in puzzle form](image)

**Computational Thinking Concept/Skills Applied**
1. Pupils
   a. Pattern Recognition
2. Teacher
   a. Evaluation

**Pros**
Enable the student to memorize Surah Al Fatihah by recognizing the words and arrange it accordingly to the right order. They will be able to identify the right word or sentence.

**Cons**
Since this is a first year student, some student might not be able to remember it. There are possibilities of student who just arrange it according to its shape and not knowing whether it’s correct or not. The teacher only call up one representative to read it, there will be student who did not participate and let the others to do it. This activity did not actually makes the student fully utilize their thinking skills into solving the problem.
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## Table 2: Proposed teaching method with CT

<table>
<thead>
<tr>
<th>Subject</th>
<th>Islamic Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1</td>
</tr>
<tr>
<td><strong>Topic</strong></td>
<td>Memorizing and Reading Surah Al Fatihah with the correct Tajwid</td>
</tr>
<tr>
<td><strong>Approach</strong></td>
<td>Proposed method with CT</td>
</tr>
</tbody>
</table>

### Activity 1
1. Teachers provide flash cards containing the words in Surah Al Fatihah.
2. Each student takes the cards randomly.
3. Students will be asked to group themselves according to the verse of Surah Al Fatihah. There are 7 verses, so there will be 7 groups. They will find the group on their own.
4. In groups, students will be asked to form the correct verse.
5. Teacher asked the students to read out loud in the correct order.
6. The teacher will listen and correct the arrangement of the sentences and pronunciation if necessary.

### Activity 2
1. Teachers provide flash cards containing relevant tajwid for Surah Al Fatihah.
2. Students are asked to match the tajwid flash cards to the correct word.
3. Students are asked to read out loud with the correct pronunciation of the tajwid.
4. Teacher will listen and correct the readings if necessary.

### Teaching Materials

**Sample flash Cards of Surah Al Fatihah**

<table>
<thead>
<tr>
<th>Mad Asli</th>
<th>Mad A’ridh Lissukun</th>
</tr>
</thead>
</table>

**Sample flash Cards of Tajwid**

<table>
<thead>
<tr>
<th>Al Fatihah</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>بسم الله الرحمن الرحيم</td>
<td>Bismillah</td>
<td>The name of Allah</td>
</tr>
<tr>
<td>مرحباً وآياك</td>
<td>Hello and How are you?</td>
<td>Hello and How are you?</td>
</tr>
<tr>
<td>رحمة الله</td>
<td>Mercy of Allah</td>
<td>Mercy of Allah</td>
</tr>
<tr>
<td>التّسْتَقِيمَ صرِّط</td>
<td>Straight path</td>
<td>Straight path</td>
</tr>
<tr>
<td>طَمَرُوا</td>
<td>Curved</td>
<td>Curved</td>
</tr>
<tr>
<td>تَبَرَّكَ اِبْنُ مَلَك</td>
<td>Blessed is the Son of Malak</td>
<td>Blessed is the Son of Malak</td>
</tr>
</tbody>
</table>

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The table above provides a structured approach to teaching and learning the Surah Al Fatihah with the correct Tajwid, using a combination of visual aids and group activities to enhance comprehension and retention.
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#### Example of activities

<table>
<thead>
<tr>
<th>Computational Thinking Concept/Skills Applied</th>
<th>Activity 1</th>
<th>Activity 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Pupils</td>
<td>1. Pupils</td>
</tr>
<tr>
<td></td>
<td>a. Decompose</td>
<td>a. Abstraction</td>
</tr>
<tr>
<td></td>
<td>b. Logical Reasoning</td>
<td>b. Pattern Recognition</td>
</tr>
<tr>
<td></td>
<td>2. Teacher</td>
<td>2. Teacher</td>
</tr>
<tr>
<td></td>
<td>a. Evaluation</td>
<td>a. Evaluation</td>
</tr>
</tbody>
</table>

#### Pros

1. Enable the student to memorize Surah Al Fatihah by recognizing the words and arrange it accordingly to the right order.
2. All student will participate as they need to find the correct combination of the verses to form a group.
3. Student need to think on how to arrange the word into the right sentence.
4. Students will help each other to memorize the verse and the meaning, and also how to pronounce it correctly according to the tajwid.

#### Betterment

With the proposed method, teachers will be able to make all students participate, build up their self-confidence through finding their own group activity and finally taught them to find solution on their own with teacher’s guidance.

With the proposed method, it will help in increasing the percentage of student’s involvement. CT taught students on how to solve problem on their own and how they can cooperate with team members to find the correct solution.
(5) Summary

Computational Thinking becomes an approach to current teaching method that adapt computing process used by the computer. It has six main concepts which are decomposition, abstraction, evaluation, pattern, logical reasoning, and algorithm. By using BIC model, the teaching method will trigger the students on their critical thinking, creativity, collaboration skill, and communication (4C). The technology will be used to facilitate the teaching process and make the process more fun. Even though CT sounds technological, however, the method can be applied to any subject in school. By applying one or more concepts of CT in teaching the subject, the student not only can learn fast but also enhance their 4C skills. CT gives the students to master the subject domain but also prepared the students to be innovative in their job employment in the future.

References


