IMPACT OF COMPUTATIONAL THINKING AND COMPUTER SCIENCE (CTCS) TEACHING TECHNIQUE AT SELECTED SCHOOLS IN SARAWAK: A QUALITATIVE ANALYSIS

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ABSTRACT

Computational thinking and computer science (CTCS) is an educational approach that involves a four-stage process involving concepts of decomposition, pattern recognition, abstraction, and algorithm that promotes greater levels of thinking. Initially exclusive to computer scientists, it has further developed from the realms of computer sciences into a skill to be mastered by all levels and backgrounds of education in numerous countries. In the context of Malaysia, CTCS was incorporated into education in 2017 through the integration of elements of Information Communication Technology into almost all subjects at both primary and secondary levels. Between 2017 and 2020, the Faculty of Computer Science and Information Technology (FCSIT), UNIMAS conducted teaching certificate program for teachers, and outreach program based on digital making, programming, and robotics for students to increase their readiness in digital knowledge through computational thinking and computer science (CTCS). This paper aimed to explore the impact of the implementation of CTCS in the teaching-learning process by obtaining descriptive information through interviews with selected teachers and students. The findings showed that the reception of CT was positive as teachers found teaching easier and students showing greater interest in learning. The reception stems from CT's ability to promote critical thinking, problem solving, and communication skills, consequently leading to greater collaborations between students and teachers.

Keywords: Computational Thinking, Problem Solving, Critical Thinking, Communication, 21st Century Education

INTRODUCTION

When one observes a computer scientist finding a solution to a complex problem, they will apply the processes of computational thinking (CT) for their approach. A process initially made exclusively to computer scientists, Wing (2006) suggested that CT should be taught to all levels of education as it is "a fundamental skill for everyone, and not just for computer scientists". CT is a four-step process that involved the concepts of:

i. Decomposition: Separation of a complex problem into smaller parts,
ii. Pattern Recognition: Similar characteristics are identified from the separated parts,
iii. Abstraction: Important details are extracted from each similarity,
iv. Algorithm Construction: Solutions are formed based on important details taken.

Up to this point, most educational technology scholars agree that the common denominator that exists in CT is that it is an important 21st-century skill that develops the skills and abilities used for complex problem-solving (Voogt *et al.*, 2015). This led to numerous countries taking note and applied CT into their syllabus as it has proven to promote a student's ability to think critically and solve complex problems (Lockwood & Mooney, 2017). Some examples of countries take in the form of Finland where their reform of its two-track education system into a compulsory nine-year system called *peruskoulu* creates emphasis on the need of 21st century skill development such as critical thinking, problem solving, and communication skills to adapt to the 21st century competency (Lavonen & Korhonen, 2017).

Another example of such is Singapore where it has implemented the elements of CTCS such as problem solving, critical thinking, and algorithmic thinking in the primary and secondary levels of education, along with the implementation of programming subjects which involved the use of programs such as Beebot, Scratch, and Kibo to name a few (Seow *et al.*, 2019). This stems from Singapore change of approach to its education by changing the dynamics of the teaching process by allowing its students greater engagement. This according to Ng (2021) is an approach from changing the need of quantity to the need of quality.

Malaysia has followed suit in this trend through its implementation of CT in 2017 with the Ministry of Education (MoE) offering subjects such as Information Communication Technology (ICT known as *Teknologi Maklumat Komputer @* TMK) for the primary level and Basic Computer Science (known as *Asas Sains Komputer @* ASK*)* for the secondary level that exposes students to some basics of CT (Lapawi & Husnin, 2020a). In addition, teachers were also prepared for this shift as the CTCS teaching program was organized, a comprehensive course to provide teachers with knowledge and guidance on how to apply CTCS teaching technique in the classroom with the objective of preparing teachers in schools across Malaysia to improve their teaching method to create greater impact from the teaching-learning process. This course in particular was held nationwide, and for the purpose of this study focused on the CTCS course held in Sarawak, a state that is known for its greater geography and diverse school backgrounds of mainly urban and rural settings. In addition, this study aims to further suggest its effectiveness being incorporated into the syllabus.

LITERATURE REVIEW

The discussions around CT in education has been debated ever since its emergence. The initial proposition of CT by Wing (2006) states it as a thinking process of computer scientists can be highly beneficial to everyone from all fields due to its multiple levels of abstraction required in its problem solving, Aho (2012) describes CT as a thought process in where the solutions are represented as steps and algorithms in the problem-solving process, and Shute *et al.* (2017) describing CT as a scientific method of thinking that holds a number of practices that works closely with each other that gives perspectives at approaching problems. Numerous definitions of CT exist with similar beliefs that there is emphasis on skills, behavior, and characteristics that dictate the problem-solving ability of a person (Voogt *et al.*, 2015).

These threads of discussions have consequently led to the efforts taken in applying CT in education, majorly in K-12 education where pedagogies were created (Grover & Pea, 2013) and where this type of education was initially reserved for higher education (Guzdial, 2015). This was the trend for many educational structures in numerous countries such as Finland (Lavonen & Korhonens, 2017), Singapore (Seow *et al.*, 2019), and Malaysia (Lapawi & Husnin, 2020b). This all stems from the changes that are currently happening in education in which transfer of knowledge has now gone into the development of one's being to develop the competencies, abilities, and talent in promoting a better quality of life (Kapur, 2023).

The implementation of CT into the syllabus by these countries can be attributed to its problem-solving approach that is highly efficient and systematic as it helps one to understand complex and simpler problems through identifying the best approaches and limitations of methods (Mohaghegh & McCauley, 2017). This is an aspect needing development as socio-digital revolution has brought changes to the way of the current world in daily life such as livelihoods, works and studies (Ezeamuzie & Leung, 2022).

Ezeamuzie & Leung (2022) states that the approaches that have been taken led to many positives towards students in terms of skills and also personal development such as confidence, which has led to its implementation to the curricula of many countries. This change also is believed to be better developed at early stages of childhood education as their CT-related skills can be developed as early as developing areas such as reading, writing, and arithmetic (Su & Yang, 2023).

RESEARCH METHODOLOGY

The qualitative approach was taken for the study as it is the best method for a study that explores and provides answers (Tenny *et* al., 2017) as the data gathered mainly relies on descriptive answers found in past studies and first-hand perspectives of interview respondents. This was obtained through gathering data provided from experiences, perceptions, and behaviour, all of which cannot be explained by the quantitative approach.

Due to the inquisitive and critical direction of the study, the constructivist paradigm was utilised as it provides researchers an avenue of facts that may not be representative of other traditional theories (Amineh & Asl, 2015), making its approach as a means of discovering a variety of aspects surrounding the CTCS technique. The population of this study was 8 respondents consisting of 4 current teachers based in Kuching, Sarawak who attended the CTCS teaching program between 2017 to 2019, and 4 students who were secondary students of the teachers.

An in-depth interview was conducted digitally through Zoom with a semi-formal structure to allow more expression and freedom for respondents to elaborate their perspectives. Teacher respondents were asked a set of questions that revolved around their experience attending the CTCS teaching program, such as their initial reactions towards the introduction of CT into the syllabus, the opinions of CT and students' acceptance towards the change of teaching approach, views of CTCS teaching in practice, and interests of students through favoured and least favoured approaches. Student respondents were asked a set of questions that revolved around the teachers approaches to learning in the classroom, the students' involvement through various approaches of teaching conducted by the teachers, and their interests towards the subjects taught by their teachers.

For the analysis of collected data from respondents, the interviews were transcribed and transferred to NVivo 12 for data extraction and categorization. Content analysis was utilized for the study to highlight important points made by the respondents from the questions asked in the interviews to be made as reference. Three main categories were made which are labelled initial reactions towards CT, teacher perceptions of CT, and student perceptions on application of CT by teachers. Each category has its own respective sub-categories that provides further elaboration to make referencing a simpler process.

There were certain limitations that became challenges for this study. It can be observed through the lack of respondents that the researcher had to face as availability and willingness of respondents posed as the main issue. The geographical setting of this study is another main challenge as some of the respondents are located in areas where cell reception is not adequate to hold a stable connection for video calls, consequently leading to problems in accessibility as some respondents were located in rural areas that has limitations in internet access. A further investigation towards approaches in learning is suggested to find a plausible teaching approach that can be utilized in uniform.

FINDINGS

Table 1: Summary of Respondents

Respondent Level		**Number**	
Teacher		4	
Student		4	
Gender		**Level of School**	
Male	6	**Primary**	2
Female	2	**Secondary**	6

Table 1 represents the summary of the respondents that have taken part in the study. The experiences of CTCS were studied by asking multiple questions. Some of these questions required the teachers to share their experiences of CT when it was first introduced into the syllabus and their knowledge towards CT. Their reaction was then explored further through their perception when obtaining first-hand experience of CT through the CTCS teaching course requiring them to elaborate on their experience in a theoretical and practical setting. From the theoretical aspect, this required teachers to elaborate on their opinion whether CTCS was beneficial or otherwise in class. Meanwhile, the practical aspect required them to elaborate on whether the students accepted this approach and how it impacted their students' (both excellent and weak).

The practical aspect was then interlaced with questions asked towards the students by exploring their interest towards their favoured and least favoured subjects taught by their teachers, also requiring them to elaborate on the reasons. This was then explored requiring students to elaborate whether their academic performance is affected by the change to provide

insight on whether the teachers have practiced the CTCS teaching technique during class, which was to observe whether interest has directly impacted academic performance.

The observed impact was explored by requiring teachers to elaborate on their experiences when they practice the CTCS teaching technique in class through certain aspects such as their students' involvement in class through their thinking, problem solving approach and communication among themselves. This was intersected by redirecting to the students' perspective on their teachers' methods in teaching by asking them to elaborate whether they are more involved in the teaching process. This was followed-up by exploring the teachers' most frequently applied method by the teachers, followed by the students being required to elaborate on their more favoured and least favoured methods by the teacher. This is to observe whether the teachers' perspective correlates with the students' experiences in the class.

1 CTCS as an Easy-to-Accept Approach

Two of the teachers are found to be well-versed with CT given their backgrounds in IT and experience as the school being supervised as a Junior Innovate, a program by Curtin University that completely utilises CT respectively. The latter stated the experience never involved the utilisation of CT specifically in science or any other subjects.

> *"CT for me is not necessarily new. The labelling is maybe new, but the gist of it has long existed, only we do not give it as the label of CT that time. I can easily relate with it, which is why I find it easy. Plus, if our field is basically problem solving, of course problem solving you have approaches, right? CT is a systematic approach to solve a problem, a good approach because it can be shown to these students on how to solve a problem. In fact, our daily life we indeed are involved in the problem-solving process, not necessarily in my subject, but in mathematics, in science, and so on."*
>
> *(Teacher Respondent 2, Male, Secondary School)*
>
> *"My current school is a school that is still under the supervision of the Junior Innovate, a program under Curtin University that highly involves CT. Science subjects are subjects based on facts and logic, same goes to CT that has fact and logic. Many aspects in CT can be applied in sciences. So, for me, the course held in UNIMAS is an early exposure because before this we were really never exposed specifically on the utilization of CT. It's because we pressed on Paddle, in education only. Until now we still use that, even though*

we're not too skilled at it, however, we could apply it when teaching in class."

(Teacher Respondent 4, Male, Primary School)

One teacher pointed out that CT was thought to be a different kind of approach in the thinking process, which shows there exists a level of understanding of CT before its introduction into the curriculum.

"In the beginning I presumed CT was an approach that's different from other thinking processes particularly PDP (teaching & learning). Once I attended the workshop and given in-depth exposure, I find that CT promotes a thinking process that really helps solve problems, especially for me with students in class."

(Teacher Respondent 3, Male, Secondary School)

One teacher was quick to share concern regarding whether students would accept this approach. Instead, after attending the CTCS teaching course, the teacher found it to be very suitable even for weak students.

"The way the teacher made the algorithm one by one, because I had taught RBT (technology design) one by one from designing ideas. For weak students, they can understand, they can remember because it is very suitable even if students are weak when consciously they say "Wah there was a step, teacher". That step being the algorithm. From here, the students can catch it even if the student is very weak, even if they're in recovery (below very weak students). From my experience recovering students seems better when using algorithm, and decomposition. Smart students will design well and evaluate, prepare materials, and create the product. It doesn't matter if they are (from) Science, Bahasa Malaysia, English; algorithm is very suitable. It is the most suitable for primary students, including the weak students. As long as they can say, "Okay I know now first is draw, look for materials", this means it is easy to capture accurately and accepted."

(Teacher Respondent 1, Male, Primary School)

2 CTCS as A Problem-Solving Approach

The narratives of CT from a theoretical and practical perspective were explored to understand the perception of teachers. The theoretical perspective observed how teachers view the modules and

methods of applying CT could be implemented during the teaching process. Meanwhile, the practical perspective observed the response on how modules and methods of applying CT to students. This question is then further explored through the receiver being the students by asking the student's interest in the subject and the teaching technique of the teachers.

From a theoretical standpoint, it was discovered that all the teachers find it to help in class very well. Practicing it only further proves the assumption made to CT as being well-received by students. 2 teachers agree that CT is a part of daily life and believe it to be an approach that can easily be applied to any subject. It is also believed that the core elements of CT have been applied to the teaching methods of teachers.

> *"Okay, if we observe problem-solving, it is there in add-maths, mathematics, and in various subjects. Even in computer sciences it's actually there, but the characteristics of problem-solving itself is specific to a subject. But then, CT in that is generalized. Only the process (is) applicable to any subject, from that context, from the point I have observed; CT can be applied to any subject."*
>
> *(Teacher Respondent 2, Male, Secondary School)*
>
> *"From the aspect of teaching Science, I will definitely use it. For us in science, we have always been stressed on using textbooks completely by the MOE, even any activities related to science. For example, we conduct an experiment; we instantly use the stated experiment materials to teach a topic and from there we stressed using CT in the experiment. It's because it's not far from it, so for me it's no problem."*
>
> *(Teacher Respondent 4, Male, Primary School)*

One teacher suggests that CT is not only just a means of an essential problem-solving skill, but it also helps to understand human behavior through its approaches, along with supporting that CT can be applied to any subject due to its nature of being both a problem-solver and thinking process.

> *"As we know, CT is an essential skill in problem solving, and understanding human behavior is a basic concept in computer science. Besides that, my students have the chance to apply steps in arranging, analyzing, and also presenting data or ideas logically and systematically. Using the methods in CT such as decomposition, pattern recognition, abstraction and also construction (algorithm); these are used for solving problems. CT isn't just for subjects such as computer science technology or computer science, it can*

also be expanded to other subjects because it undergoes a thinking process."

(Teacher Respondent 3, Male, Secondary School)

One teacher believes that in theory it can help to attract the students' attention and solidify the theory when testing through a particular subject (being physical education) which students find boring, but changed when CT was applied. This being the elaboration of the teacher's concern when CT was first introduced.

"From my experience, for example in moral education, PJ (physical education), sometimes the students (find it) boring. When broken into groups, they will undergo decomposition, breaking a scenario getting smaller and smaller. From that, the students are attracted to it, wanting to find the answer at the end. It was acceptable by them, meaning that's how they learn, one by one."

(Teacher Respondent 1, Male, Primary School)

3 A More Engaging Approach for Students

As the teachers' perspectives on CT have been explored in the prior section, this study analyzed the perspective of students.

3.1 Frequent Applied Techniques and Student Involvement

The study found that teachers have definitely used methods that involved the concepts of CT through a number of activities, one of which was made prevalent was presentations. From this approach, it was discovered that interactions are more frequent which piques interest in the subject taught and promotes communicative skills between peers and teachers. The students strongly prefer presentations as one of their favored approaches by their teachers.

"One of which he tried to do is group presentations, presenting in groups, and group discussions… That's one of the better ways for me to understand and I am more interested to learn computer sciences, because I can say I really like to learn (subjects) related to technology."

(Student Respondent 2, Male, Secondary School)

"My teacher teaches in many ways. With the mixture of traditional and modern style of teaching, and the way he teaches involves us a lot, especially when it comes to group

work like presentations, discussions, or when we need to present our answers (presentation) in front of friends."

(Student Respondent 3, Male, Secondary School)

"We frequently have presentations and learning in groups. We also do frequently interact with the teacher like model designing. For me, it is very productive."

(Student Respondent 4, Female, Secondary School)

From this instance, the study found that some students find that approach to be a great way of communicating with each other by sharing their ideas and work collaboratively that helps to expand the ideas through critical thinking. This not only helps the students to improve their comprehension of the subject, but also assists the teacher in guiding the students to understanding what was taught in the class. The study found that two students excitedly expressed why presentations are very impactful to them.

"I like to make presentations in front of class. When I conduct a presentation in front of class, I'm the one who explains the results of what was taught by the teacher. I would reexplain what I learned with friends. Besides that, I get to understand what I learned during the presentation. So, for me, it is very positively impactful to me, but also to my friends who present in front too."

(Student Respondent 2, Male, Secondary School)

"I know I like the technique of teaching through presentations in front of class because it can like, give me a chance to hear my friends' ideas, where our ideas can be expanded greater and I can understand the way they think."

(Student Respondent 4, Female, Secondary School)

Another example of approach favoured by the students are through slides provided by the teachers. It was found that the main reason behind some students enthusiastically liking slides is its availability and amount of information provided in the slides, allowing them to understand better.

"Slides are very simple yet hold intricate amount of information, and it makes it easier to understand. My teacher will teach by projecting the slide while explaining what's projected

on the screen, and often time he would show videos and slides about the subject when we learn, and it helps us to understand much faster."

(Student Respondent 3, Male, Secondary School)

"The most interesting (approach) I guess would be the slides approach since the teacher will compile all the info in one slide, plus it is not too wordy and it also has videos, or pictures."

(Student Respondent 1, Female, Secondary School)

In terms of the involvement of students during the teaching process, it was found that all students agreed that the teachers really involved the students a lot by asking questions, creating exercises and presentation works, all of which promote critical thinking and communication skills. The teachers took a student-centric approach, with there not being much stress on the teacher being the point of attention.

"He does frequently involve the students. He would usually ask whether we understood the video or any picture (shown). If we do not understand, he will explain further."

(Student Respondent 1, Female, Secondary School)

"Students themselves present what they understood. When it is the student that presents, the teachers can see where the level of understanding of the student is at."

(Student Respondent 2, Male, Secondary School)

"The way he teaches involves us a lot, especially when it comes to group work."

(Student Respondent 3, Male, Secondary School)

"Definitely the teacher will. Say if we present, the teacher will ask questions based on what we presented. Through this way, the teacher can know what the level of our understanding in a subject is."

(Student Respondent 4, Female, Secondary School)

3.2 Least Favoured Techniques and Student Involvement

In addition, the study explored the least favoured approaches by students. Most students agree that textbook-teaching is the least favoured approach due to several reasons ranging from the excessive use of words, disregarding of students' understanding towards the subject taught, to lack of visualisation. This also found there is low involvement of students with regards to least favoured approaches.

" Obviously, there are certain teachers teaching only using textbooks, which is boring. Since it has too many words, it becomes hard to understand."

(Student Respondent 1, Female, Secondary School)

"Using textbooks without involving the students. The teacher not asking questions whether the students understand or not, the student themselves of course will say they do when actually they don't."

(Student Respondent 2, Male, Secondary School)

"A not so favourite way of teaching would be reading something on the book (textbook). Not only does it lack explanation, it also lacks visualisation and it's hard to make us understand better."

(Student Respondent 3, Male, Secondary School)

One student on the other hand expressed dissatisfaction in gallery walks. A gallery walk is where students are required to set up a booth presenting a certain topic to all peers for conveying information simultaneously. The reason being the inability for the teacher to pay full attention to a group and not able to instantly provide corrections if a mistake was made.

"I am less interested in learning by gallery walk. From this, we will go to every table in turns, and the teacher will just supervise lightly plus go to every table. Simultaneously, other tables will continue sharing information, continuing the presentation. This causes the teacher to not know how to correct it because the focus divided."

(Student Respondent 4, Female, Secondary School)

DISCUSSION

It is made apparent that the teachers agree that CT is ideal for the students as it poses itself a means of problem solving and forming a solution based on a given scenario. As it is seen as a systematic and a step-by-step process that can be identified by students, it supports the findings by Voogt *et al*. (2015) that CTCS can help students in not only their thinking abilities, but also nurture their creativity. Furthermore, CTCS could also be promoted towards struggling students who find it difficult to master a topic in any subject and helps to foster their abilities in comprehension.

Teacher respondents pointed out that CTCS is an approach that definitely can be applied for not only those in the STEM field, but also for those in the non-STEM field as the elements in CTCS are favored by teachers and students alike. Mohaghegh & McCauley (2017) emphasizes that CT can be benefited by anyone from any background as it can be considered as the 21st century literacy, indicating that CTCS can be applied in any subject. Subjects stated by respondents include language subjects such as English and Bahasa Malaysia, and even non-technical subjects such as Moral Education and Physical Education.

Two concepts were emphasized as highly favored by students according to teachers being decomposition and algorithm. This is due to the notion that the two concepts allow for a more engaging and collaborative discussion between teachers and students. From the students' perspective, it enabled them to be more attracted to the subject taught as it was made simpler into smaller, more understandable parts as pointed out by some teachers. Shute *et al.* (2017) points that CT can be suitably facilitated in many approaches with an emphasis on programming (via Scratch) as one example due to it being built with the objective of assessing and training a student's problem-solving skill. This relied on a student to be able to break down problems to smaller parts and come up with a solution to it, showing that there are approaches that can be used to accommodate CT in the classroom.

Student respondents pointed out that the teachers have utilized approaches that promote great levels of collaboration, engagement, and creativity through presentations and discussions. These two approaches have made it possible to communicate with each other much better through sharing ideas with peers and discourse among each other, along with giving them the opportunity to show their creativity in how they express their ideas. This stems from the fact that students are given full control in the classroom with the guidance of the teacher to aid them in explaining the ideas, giving the teacher an understanding of the level of students' comprehension towards the subject and helps to tailor on the approach that the teacher can take to assist the students in mastering a subject better. This provides further evidence based on the findings of Ezeamuzie & Leung (2022) that CT can bolster the skills of students such as critical thinking, problem solving, and communication which consequently helps to build students' confidence through interactions between students and teachers.

The student respondents have also pointed out that approaches that utilized visual aids with more words than pictures are a reason towards the disliking of textbooks as engagement

and attention tends to drop over time. In addition, the approach of a gallery walk is a deterrent for students as it decreases the engagement with the teacher that, subsequently leading to a lack of confidence with the information they have put for display. This shows that collaboration with the teacher plays a key role in a student's interest when undergoing the teaching-learning process as some depend on engagement with the teacher to learn and understand better.

CONCLUSION

CTCS has shown itself to be an effective approach in teaching due to its ability in solving complex problems through the processes of decomposition and pattern recognition. Both respondents find a great level of engagement and collaboration when CTCS is applied in the teaching-learning process as both sides requires input from each other; students showing their level of understanding through approaches such as presentations and discussions, and teachers understanding the level of their students' comprehension based on what was presented. Favoring the stated approaches shows that an effective session relies on high levels of collaboration and engagement between students and teacher, as it directly affects the interests of students towards the subject taught.

It should be noted that there is a level of encouragement that the development of CTCS should be pursued as it can also be applied not only in classrooms, but also in daily life through interactions and daily habits. Teachers have found that its application has left students to be more engaged and understand subjects better disregarding the field of the subject. In addition, some teachers have noted that CTCS can be applied for students who are struggling in certain subjects as the process of decomposition helps to break down a complex into smaller compartments that allow them to understand things better.

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