Computational Thinking Best Practice for K-12 Students

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Abstract

This paper explores the intersection between current methods for introducing and teaching computational thinking (CT) to students in kindergarten to twelve grade (K-12) and culture. Available literature in CT, cognitive theory, and K-12 pedagogy will be used to gather and analyze the methods available today. Our goal for this paper is to gain an understanding of the current state of best practices for introducing CT to propose the best framework for scholars and practitioners to focus on.

Introduction

Initially introduced by Wing (2006), computational thinking (CT) is a set of thinking skills and approaches that are deemed necessary to solve complex problems using a computer. Wing (2006) proposed that these skills would be valuable for an individual's chance of employment, as society will demand more usage of computers to solve its needs and issues. Despite the groundwork laid, the efforts to introduce and teach CT to students have faced considerable challenges. One that is crucial is "What are effective ways of learning (teaching) computational thinking by (to) children" (Wing, 2008, p. 3720). Scholars have stepped up to the challenge and proposed different methods in answering this particular question. Lee et al. (2011) showed that introducing CT to youths in practice starts with modeling and simulation, robotics, and game design and development. Lu and Fletcher (2009) called for a different approach in introducing concepts of coding by not using programing language and opt to use everyday language that is appropriate to the grade level. Weintrop et al. (2016) argued that CT is a valuable asset that is beneficial enough to be presented by itself and also to augment mathematics and science classes.

This paper explores available methods in introducing CT. The research question that drives this study is, "what are the common themes amongst the available approaches in introducing CT to K-12 students?" This study will then assess these approaches along with skills associated with CT, such as abstraction and decomposition, heuristic reasoning, and knowledge of computer science concepts, and synthesize the findings with cognitive theories and K-12 pedagogy literature (Weintrop et al., 2016). Aspects associated with the skills that can be analyzed are the close connection with programing language, the necessity to attain and retain concepts, and the usage of CT in problem-solving.

As CT is strongly connected with coding and programming language, in addition to a large number of methods of introducing CT involves coding, it is necessary to explore possible ways and models in teaching a new language to students. One model that has been used extensively in teaching English for students with English as a native language and students with English as a second language is the Sheltered Instruction Observation Protocol (SIOP) Model (Echevarria, Vogt, & Short, 2008). Supported by fifteen years of research, SIOP model articulates the necessary components in not just furthering knowledge of English for native English speakers but also introducing and retaining a foreign language for non-native students (Echevarria et al., 2008). The scientific nature of this model is encouraging as it can help the effort in creating a working model for introducing CT to K-12 students.

In addition to programming language, CT also involves knowledge and specific information that students will need to attain. The idea of achieving new knowledge and issues that can arise from it is not wholly unique in the world of education. One model that tries to address the attainment of concept is the concept attainment model. The aforementioned model seeks to address the attainment of concept through three phases: presentation of data and identification of concept, testing attainment of concept, and analysis of thinking strategies (Joyce & Weil, 1980).

The process of transferring CT does not stop after students have attained the knowledge and skills. As argued by Wing (2006), CT skills are used for numerous purposes, namely problem-solving. In facilitating transfer and problem-solving in the classroom, Ormrod and Davis (2004) proposed several suggestions. Some of these suggestions are students need to learn information meaningfully and thoroughly, students should also learn problem-solving strategies at a meaningful level, students have a mental set for transfer, and some prerequisites skills should be practiced until they are learned to the point of automaticity (Ormrod & Davis, 2004).

Looking at commonality amongst the available methods in introducing CT and analyses of aspects of CT through the lens of cognitive theory and K-12 pedagogy that available methods try to address, this paper will then propose the best framework for practitioners and scholars to use in the classroom and future research in CT.

Method

This paper uses a literature review approach to gather the data by analyzing the methods and findings of the available literature (Lye & Koh, 2014). Our goal is to unearth the ways that are used in teaching CT across cultures and to determine whether or not culture is considered when it comes to this emerging field. To be included, papers must have been peer-reviewed and be more than two pages, to eliminate editorials, book reviews, and viewpoints (Aloini, Dulmin, & Mininno, 2007). This paper gathers publications from the period of 2015 to 2019 to get the latest trend in CT, rather than focusing on the formative years. On cognitive theory and K-12 pedagogy, this paper utilizes both peer-reviewed papers and notable books that might have preceded the establishment of journals in their respective fields. In total, 49 peer-reviewed articles on teaching and introducing CT were selected. Although the author was able to find more than the selected number of articles, some were removed because they were written in foreign languages in which the authors are not proficient. Also, some were excluded because they discussed CT as a tool to assess other variables rather than the focus of the study.

Findings

From the findings, it is apparent that hands-on delivery is the preferred method of teaching and introducing CT. Despite the fact, having diversity in the method of delivery is needed to bring a more balanced and complete approach. The only lecture-based transfer of knowledge studied was on pre-service teachers to better equip them with CT knowledge and skills (Yadav et al., 2014). Perhaps, the 17 cases of both lecture and hands-on activities are an encouraging sign that lecture still has its place in CT knowledge transfer.

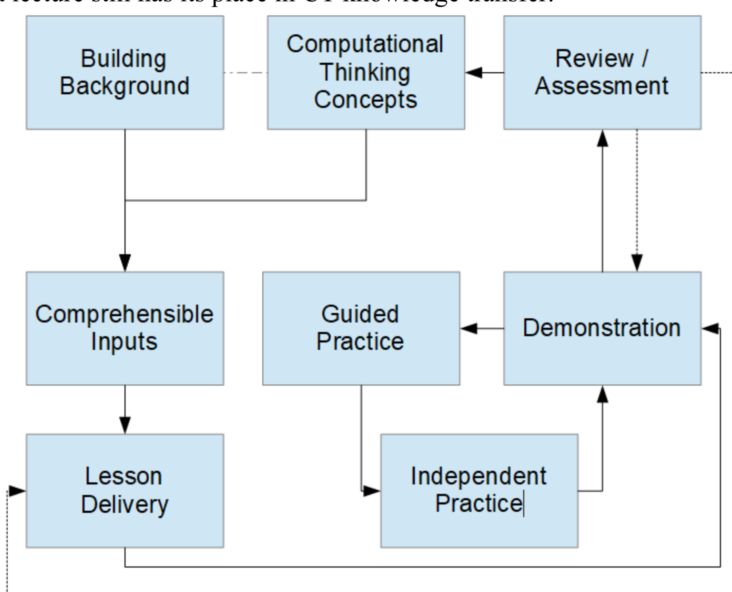

Figure 12. Framework for introducing and teaching CT

The framework that this study proposes highlights the importance of both types of delivery. Recognizing that no two students are alike in how they acquire, process, and retain knowledge, the framework will offer a holistic mean of introducing and teaching CT, as shown in figure 12. Similar to SIOP, teachers will use CT concepts and building background to create comprehensible inputs. This way, the concepts of CT will only be delivered according to the student's level, cultural background, and language proficiency. Once the inputs have been compiled, the teachers can then deliver the lesson. Delivering the lesson will start with a lecture, followed by a hands-on activity.

The hands-on activity is designed as a scaffolding to help students learning the concepts and skills of CT in an environment that nurture their self-efficacy. The idea of using scaffolding is not entirely new in CT as some of the selected articles for this study used it in their research (Bagley & Rabin, 2016; Basu et al., 2016).

The scaffolding itself is a loop. After the teacher demonstrated how to apply a concept of CT, the students will then use the concept under the guidance of the teacher. One the teacher is satisfied with the students' performance, the students will then apply the CT concept independently. The loop will only break when the teacher is confident with the performance of the students. In a case where an additional lecture needed, the teacher has an opportunity to do so. The cycle will then repeat after a concept has been thoroughly processed by the students.

Building Background

When building the background to be used to create comprehensible inputs, teachers will need to take account of the student's level, cultural background, and language proficiency. The student's level will determine which concepts to be introduced and taught. Basic concepts, such as "problem-solving" and "decomposition," are appropriate for students in lower grades. More complex concepts, such as "reusable functions" and "objects," may not be suitable for students in lower grades and can be introduced later in K-12. Using terms and concepts of CT by Selby and Woollard (2013), an example of how to break them by levels is shown in table 1.

Table 1. An example of terms and concepts by level, culture, and language proficiency

Terms/Concepts	Grade level	Culture Adjusted Country A	Proficiency Adjusted AP students
A thought process	2-6	2-6	K-6
Abstraction	2-8	2-8	K-8
Decomposition	2-8	2-8	K-8
Logical thinking	K-6	K-6	K-6
Algorithmic thinking	6-12	4-12	4-12
Problem-solving	4-12	K-12	2-12
Evaluation	4-12	K-12	2-12
Generalization	K-6	K-6	K-6
Systems design	9-12	6-12	6-12
Automation	8-12	6-12	6-12
Computer science content	8-12	6-12	6-12
Modeling and simulation	9-12	9-12	9-12

Once teachers have broken up these concepts by level, they will then have a holistic picture of the students' progression from K to 12 grade. This will then be used in the next factor they will need to consider, cultural background. Some ideas and concepts can be more natural in one culture when compared to others. Teachers need to recognize this and adjust the level where the concepts should be introduced. Finally, the language proficiency of the students will need to be taken into account. Because of the complex terms and ideas that are inherent in CT, students who perform better than their peers can certainly grasp them sooner and better. After the teachers have taken all of the aforementioned into the model and adjusted the grade accordingly, the final version should look like table 1.

Lesson Delivery and Hands-on Activities

As discussed before, delivering the lesson will start with a lecture. Having the appropriate level of ideas and concepts for the level, culture, and language proficiency should keep the students' engagement between 90 to 100 percent. This lecture will then be augmented by hands-on activities that are in line with the lecture. Teachers can include many activities in the lesson. Some activities that this study had presented, such as programming using a programing language, programming using software (scratch), robotic, and modeling software, can augment the delivery of ideas and concepts. While it is admirable to try and use new activities to cultivate CT skills, teachers will need to stick to what has been proven to work. An excellent example with less than desirable results is how Tsai et al. (2017) tried to introduce CT by using Microsoft office products such as PowerPoint. Once again, the teachers need to know different tools and activities that can help in teaching and introducing CT. In addition, the teachers themselves will need to be comfortable using the tools and doing the activities. The hands-on activities are considered to be scaffolding activities that will slowly shift the responsibility to the students. From the review of literature in CT, scaffolding is something that is used by several selected studies. Scaffolding itself is something that

SIOP model suggests teachers use in their classrooms. In the proposed framework, the hands-on activity portion is a loop that can only be broken when the teacher is satisfied with how the students are progressing. Review and assessment is next after the hands-on activity.

Review and assessment

Much like any other subject, review, and assessment of the delivered material are needed to ensure proper delivery. Teachers will need to set up baselines and monitor the progress of the students. This information, in addition to the changing grade level, culture, and language proficiency, can be used to modify the terms and concepts break down. However, the primary purpose is to signal the continuation of the delivery of knowledge and repeat the process.

Discussions and Conclusion

After reviewing the literature associated with the teaching of CT, this study proposed the best framework to teach and introduce CT to K-12 students. This framework, combined both lecture and hands-on activities, aims to construct systematically comprehensible inputs that students can digest based on their level, cultural background, and language proficiency. Although this framework is aimed at the students, teachers can undoubtedly benefit from the framework also. The review of literature revealed that ensuring the teachers comfortable with the idea of CT and the delivery of CT could further help the cause of introducing CT to students, especially younger students. With that, this framework will only be effective when the teachers themselves are comfortable with the framework.

Regardless of whether CT will stand on its own or be included in an already established subject such as math and physics, this framework allows the teacher to deliver CT knowledge effectively. Also, this framework will reiterate the point that CT is not programming. The element of culture, language, and concepts will hopefully drive home the point that CT is much more than just learning how to program. Although programming can be helpful as a way to introduce concepts of CT, it should not be the focal point of the learning process. When looking at it from the perspective of the proposed framework, programming should be contained in the loop portion of the scaffolding activity.

Limitations and Future Direction

The article included in this study were only those available to the authors through the university's library research databases in the span of one semester. Also, as asserted before, only studies that were written in English were selected because of the limited language proficiency of the authors. In other words, studies written in other languages such as Chinese, Korean, Swahili, Spanish, and other languages did not make it into the final list. This study would like to highlight these studies and that the reality of them not making it into the final list does not diminish the contribution of the articles to the overall knowledge of CT.

The goal of the proposed framework is to help in teaching and introducing CT to students of all levels. The next step in this study is to apply the framework in the classroom and analyze it for its effectiveness in conveying ideas and skills related to CT. The hope is that the next generation will be better equipped in solving not just individual issues, but also issues in the society where they reside.

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