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# Exploring Ways to Develop Computational Thinking in Pre-service Teachers

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**ABSTRACT**

There are several challenges that we face in the 21st century, such as pollution and climate change. These problems are being solved by technologies such as Artificial Intelligence and Machine Learning. The significance of computing in the process of problem-solving and in day-to-day life has been acknowledged by everyone. The idea of Computational thinking was proposed by Jeannette Wing in 2006. It was well received within the education community and is now incorporated into India's National Policy on Education 2020. According to the requirements outlined in paragraph 4.25 of the policy, the current educational curriculum ought to incorporate Computational thinking as an essential skill for young children. As a result of teachers' lack of understanding of the nature of this skill, the incorporation of it into the curriculum has been delayed. In reference to this problem, this paper aims to understand the nature of Computational Thinking and explore methods to develop it in pre-service teachers.

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## Introduction

We are living in an ever-advancing and unpredictable world. The COVID-19 pandemic is one example of an unpredictable scenario which left people grappling for their lives. In the wake of pandemic, we realised the importance of Computational thinking (hereafter referred as CT). Computational thinking is computing based problem-solving, and it is widely recognized as a $21^{st}$ century problem-solving skill. Jeannette Wing defined CT as a way to solve problems using Computer Science concepts and methods (Wing, 2006). Numerous other educational researchers have also proposed the definition of CT, but no consensus has been reached.

The National Policy on Education 2020 under para 4.25 incorporates it as an essential skill that needs to be cultivated in students right from childhood (Ministry of Human Resource Development, 2020). But, to do so we must train our teachers in this skill. Current B.Ed. or D.El.Ed. Programmes run in Education Institutes do not focus on the development of their Computational thinking skills. Therefore, it is imperative to train our teachers in this important skill. Educational researchers are trying to find out different ways to develop Computational thinking in pre-service teachers. But still the research is in its nascent stage. In this regard, we framed two research questions.

***Research Question 1***: What is Computational thinking?

***Research Question 2***: What are different methods to develop Computational thinking in pre-service teachers?

## Method

The investigation retrieved pertinent scholarly articles and conference papers from sources such as ScienceDirect, Scopus, and Association for Computing Machinery Digital Library. The search query included the terms "Computational Thinking" and "pre-service teachers" specifically in the article titles. The documents from the previous 18 years were recovered. The retrieved documents were meticulously scrutinized to align with the research inquiries. Research question 1 focused on including the most frequently referenced theoretical publications that provide a clear explanation or framework of CT. For research question 2, we included all papers that specifically discussed a particular activity or method for enhancing Computational thinking skills in pre-service teachers. Excluded from consideration were pilot surveys, studies lacking validation or reliability metrics, insufficient data, and small samples.

**Result**

***Research Question 1***

There is still an issue that needs to be resolved due to the diverse interpretations of what constitutes CT. The question at hand is, "What precise definition or components comprise Computational thinking?" To address this inquiry, it is essential to examine the definitions provided by distinguished researchers and influential organizations.

The way Wing delineated CT in 2006 did not provide an objective definition of CT. The theoretical form of it was widely accepted, but it lacked the boldness to be implemented in the current curriculum due to the diverse interpretations made by different practitioners at that time. Cuny, Snyder & Wing developed an improved definition of CT. According to Wing (2011), Computational thinking refers to the cognitive process of defining issues and devising solutions in a manner that can be efficiently executed by a computer or other information-processing entity. To effectively include CT into curriculums, Aho (2011) described it as a cognitive process that involves modifying issues in such a manner that their solutions may be obtained using algorithms. In addition to Wing's concept of Computational Thinking (CT), it is crucial to be familiar with Papert's CT, as he also discusses this word in his book, "Mindstorms: Children, Computers and Powerful Ideas" (Papert, 1980). Papert's concept of Computational thinking emphasizes the significance of programming computers to empower students and introduce them to the profound concepts of Mathematics, Physics, and Probability discussed in the book. Papert (1996) argues that utilizing computers and programming as constructionist tools might enhance the logical reasoning abilities of students.

Brennan and Resnick (2012) proposed a CT framework to define the learning and progress that occurs when creating interactive media on the Scratch platform. The MIT Media Lab invented Scratch, a block-based computer programming environment that is used all around the world to teach youngsters how to program. CT has three dimensions. The first dimension is "Computational concepts" (which designers use in programming) and comprises "sequences, loops, parallelism, events, conditionals, operators, and data." The second dimension is "Computational practices" (which designers use when programming) and includes "being incremental and iterative, testing and debugging, reusing and remixing, abstracting and modularizing". The third dimension is "Computational perspectives" (how designers think about the world and themselves), which involves "expressing, connecting, and questioning."

Selby and Woollard (2013) define Computational Thinking as a cognitive process that allows for problem-solving, improved understanding of situations, and effective expression of values through the systematic use of abstraction, decomposition, algorithmic design, generalization, and evaluation. This process aims to create an automation that can be implemented by either a computing device or a human. Krauss & Prottsman (2016) define Computational thinking as a cognitive process that involves breaking down issues, identifying patterns, creating abstractions, and automating solutions via the use of algorithms.

After publishing several scholarly articles in journals and conferences about the definition of "CS unplugged" and the associated activities, Tim Bell, Ian Witton, and Michael Fellows launched the "CS unplugged" project (Bell & Lodi, 2019; Bell & Vahrenhold, 2018). The project's primary goal is to present computer science—and computers in general—to young people as an enjoyable, captivating, and intellectually stimulating field. They do not use computers when teaching the fundamentals of the subject. For them, computer science is a huge area, and programming is only a means to a goal. Additionally, CT is highlighted on their website, csunplugged.org. They cite Cuny, Snyder, and Wing's definition (Wing, 2011) and define "information-processing agent" as something that adheres to a set of commands to arrive at a solution; this agent is mostly a computing device, though it may also be a person. They make it clear that computer science and CT are not just about computers; rather, they are about people because it is ultimately humans whose problems are intended to be addressed.

After researching literature on CT skills, they identified and discussed six skills that are as follows:
(i) **Algorithmic thinking:** It refers to the cognitive process of developing algorithms.
(ii) **Abstraction**: It is concealing extraneous features and emphasizing essential ones.
(iii) **Decomposition:** It involves breaking down complex issues into smaller, more manageable ones. This allows for easier problem-solving and is a crucial stage in algorithm development.
(iv) **Pattern recognition and generalization:** It is the ability to apply a solution, or a portion of it to a wide variety of problems.
(v)**Evaluation:** It refers to determining the optimal solution to a problem.
(vi) **Logic**: Logical thinking involves utilizing preexisting knowledge to establish rules and verify facts.

***Research Question 2***

To address our second research query, it is crucial to examine empirical studies that emphasize different ways for cultivating CT skills in pre-service teachers. The researcher has identified the following strategies:

**1. Programming environment (Plugged Approach):** This approach requires the use of some programming platform to help develop Computational thinking skills in the students. The most common programming environment used by researchers is Scratch. Scratch is a block- based programming language developed by MIT Media Lab in 2007. It is a popular medium to learn programming among people of all ages.

Peracaula-Bosch and González-Martínez (2022) employed Scratch to establish an educational setting in which pre-service teachers could acquire computational thinking skills via the construction of projects. This strategy ensured that all students, irrespective of their initial skill level, were able to actively participate in and enhance their Computational thinking skills. By prioritizing a rigorous Computational thinking approach, the model guaranteed that students may begin at their existing level of comprehension and gradually enhance their abilities. This approach proved to be highly efficient in assisting those with limited or no previous experience, while also optimizing the performance of pupils who were previously acquainted with Computational thinking principles. The intervention assessed the students' proficiency in CT abilities before and after the completion of the Scratch project, revealing substantial enhancement across all areas. This suggests that the practical, project-oriented learning method was successful in cultivating these essential abilities among aspiring teachers.

**2.Virtual Learning Environment:** A neuro-computerized course is a customized curriculum that utilizes sophisticated computer-based technologies and virtual learning environments (VLE) to enhance the learning experience for students. Abouelenein and Nagy Elmaadaway (2023) designed a course designed particularly for third-year mathematics pre-service teachers with the aim of enhancing their Computational thinking abilities, which are crucial for problem-solving and comprehending mathematical topics.

The NCVLE methodology employed in this course seeks to enhance the engagement and effectiveness of teaching, learning, and evaluation through the utilization of technology. The study revealed a notable enhancement in the Computational thinking skills of students who engaged in this course, in contrast to those who did not participate. This underscores the course's efficacy.

**3. Hybrid approach:** The approach includes a combination of computer-based (Plugged) activities, in which pre-service teachers acquire Computational thinking skills through programming and computer usage, and Unplugged activities, which entail understanding computational ideas without the aid of computers. The study conducted by Voon et al. (2023) revealed that pre-service teachers enhanced their

CT abilities by including, rationalizing, and contemplating CT in their lesson plans. This progress was made possible by the hybrid method of utilizing both plugged and unplugged activities.

**4. Flipped classroom model:** A flipped classroom is a teaching method that involves two distinct phases: independent study outside of class and interactive learning experiences within the classroom. This approach enhances student preparation and leads to improved learning results. The flipped classroom concept aligns with the technological pedagogical content knowledge (TPACK) paradigm, facilitating the seamless integration of technology into educators' instructional methods.

Pimdee and Pipitgool (2023) employed a flipped classroom (FC) approach in combination with Critical Thinking Problem-Solving (CTPS) exercises to instruct third-year Thai pre-service teachers (PST) in Computational Thinking (CompThink) within the field of computer studies.

The course content was categorized into four modules: the practical use of CTPS in everyday problem-solving, the design of CTPS procedures, basic programming, and programming interfaces with digital circuits. These modules were presented in 30-minute video segments published on the Moodle Cloud LMS platform. The experimental group, who engaged in the FC model, demonstrated considerably enhanced Computational thinking abilities compared to the control group, thereby affirming the efficacy of this instructional method. Similar results were seen in a study conducted by Aprinastuti (2022) on elementary school pre service teachers, who implemented Computational thinking in a geometry course using Ignatian pedagogy.

**5. Micro-credential program:** They are short, focused courses intended to teach a particular skill to the intended audience. Bal et al. (2022) developed a micro-credential program with the explicit purpose of assisting K-8 pre-service and in-service teachers in acquiring knowledge about CT and incorporating it into their teaching methods. The creation of this program entailed gathering diverse data, including pre- and post-content questionnaires, reflection diary entries, and lesson plans, to assess the participants' progress in CT and pedagogical expertise. The findings demonstrated that the CT micro-credential courses enabled pre-service instructors to see the practicality of effectively integrating CT into different disciplines and courses. The study utilized both qualitative and quantitative data analysis to get a thorough picture of how the micro-credential course assists pre-service teachers in developing their CT skills and knowledge of pedagogy, as well as their ability to plan for their future classrooms.

**6. Educational Robotics:** It involves the use of robotics in the education to develop Computational thinking in the students. In a study conducted by Wawan (2022), participants utilized Lego Mindstorms EV3 to actively participate in hands-on robotics activities, enabling students to grasp and implement CT ideas through iterative problem-solving and modular programming. The study revealed that participants acquired a more profound comprehension of CT concepts, such as abstraction and generalization, by engaging in practical robotics tasks with Lego Mindstorms EV3. Despite early difficulties, participants successfully programmed and operated the robot, showcasing enhanced problem-solving abilities and the capacity to develop algorithms through systematic analysis. Participants saw a change in their view of learning, demonstrating that engaging in hands-on robotics activities had a beneficial impact on their perception and involvement with STEM subject.

## Conclusion

Computational thinking is a fluid concept, taking on somewhat different meanings in different contexts and level of education. Yet, this characteristic of CT enables practitioners to employ variety of methods to achieve the educational outcomes. The different definitions and frameworks reviewed in the result section highlights CT as a problem-solving skill which includes components of Problem decomposition, Abstraction, Algorithms and Evaluation. The cultivation of computational thinking (CT) in pre-service teachers encompasses a diverse range of techniques and strategies, as demonstrated by recent scholarly investigations. An effective approach involves utilizing online CT training platforms, which have demonstrated that variables such as training duration, pre-existing CT abilities, and perceived level of complexity are substantial indicators of CT proficiency enhancement.

Hybrid techniques that incorporate both plugged and unplugged activities, such as experiential learning modules, assist pre-service teachers in incorporating CT into their lesson plans, particularly for those who lack previous experience with computing. Virtual learning Environments (VLEs) and neuro-computerized models have effectively improved CT skills among mathematics pre-service teachers through the provision of focused, interactive learning experiences. Utilizing technologies like Scratch, intensive CT programs facilitate the development of CT abilities in students, irrespective of their competency levels. Research has demonstrated that the integration of flipped classroom models with Computational thinking problem-solving activities leads to enhanced learning outcomes and the development of critical thinking abilities. Integrating CT into certain courses, such as geometry, using Ignatian Pedagogy, facilitates the cultivation of fundamental CT elements such as decomposition, pattern recognition, abstraction, and algorithm creation. Micro-credential programs that prioritize CT provide a creative way for incorporating CT into an already busy pre-service curriculum, improving both understanding and confidence in CT integration. The use of Robotics also has shown substantial evidence in the development of CT skills. Ultimately, the creation and validation of tools to assess the attitudes of pre-service teachers towards Computational thinking might offer valuable insights into their preparedness and confidence. This can thereby enhance the design of training methods. Together, these approaches highlight the significance of varied, pragmatic, and situationally appropriate instruction to successfully cultivate Computational thinking in pre-service teachers.

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