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# STEM: Its Potential in Developing Students' Computational Thinking

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**Abstract.**
Computational thinking skills are a person's ability to solve problems with several passed processes. The process is recognizing patterns, decomposing patterns, compiling algorithms, making models, and doing abstractions. This ability is essential for students to master understanding aspects of computational problems. It also helps students evaluate the suitability of computational techniques to solve the problem. In addition, this computational thinking ability can also help students understand the limitations and strengths of computing techniques, apply or adapt computing tools/techniques to new uses, recognize opportunities to use computing in new ways, and apply computational strategies. The STEM approach, is learning that integrates science, technology, engineering, and mathematics to develop creativity in solving problems. The transformation of the educational process in the current era that requires a high level of technology makes STEM one of the keys to progress and innovation in developing human competence. Based on a study of more than 30 articles and research results related to the effect of STEM on student learning outcomes, we can conclude that learning using STEM has the potential to develop students' computational thinking skills. This article discusses how, theoretically, we can acquire computational thinking skills through education with a STEM approach.

**Keywords:** STEM, developing students', computational thingking

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## 1. INTRODUCTION

Many fields have used the STEM (Science, Technology, Engineering, and Mathematics) approach as a tool for development. The starting point for the emergence of STEM was during World War 2 when scientists and the military worked together to develop technology to win the war [1]. Current technological advances force educational actors to be able to develop themselves in the IT field. The role of technology in education is significant because it is included as part of the curriculum, as an instructional delivery system, as an instructional tool, and as a tool to improve the learning process [2].

STEM was developed to answer challenges in the 21st century, where students are not only cognitively competent but also skilled and creative. In STEM education, the goal

is to prepare students to compete globally and be ready to work according to the field they enjoy. STEM education is a new education system that tries to integrate some of these components into the learning process. With the application of STEM components, students are expected to be able to use the knowledge they have acquired to solve problems in their lives and accordance with the demands of work in the current era. This opinion aligns with several experts who state that applying STEM in education is a world need. Students are prepared to face the 21st industrial revolution by developing communication, collaboration, critical thinking, and creative and innovative skills. STEM education can prepare a skilled workforce in science, mathematics, and technology. The basic theory of a study dealing with STEM education should define the STEM terms discussed; there should be special attention to the STEM perspective [3]. A quality STEM program that can facilitate students will develop their talents in science, technology, engineering, and mathematics.

The STEM approach to learning will have the potential to develop students' computational thinking skills. Computational thinking (CT) involves skills or techniques that include solving tasks or problems, pattern recognition, abstraction, and formulating algorithms to solve problems or situations similar to problems [4]. Computational thinking involves solving problems, designing systems, and understanding human behavior by drawing basic concepts on a computer. Aho in [5] defines CT as a thought process by formulating issues into solutions that can be represented in computational steps and algorithms. Furthermore, computational thinking has become a topic discussed worldwide in recent years as part of efforts to bring computer science to schools [6]. According to Wing, computing will play an essential role in almost every field and profession and become an integral part of children's education [7]. With computational thinking, a person will be able to understand the quantifiable aspects of the problem, evaluate the suitability of computing tools and techniques to the situation, understand the limitations and strengths of computing tools and practices, and apply or adapt computational tools or techniques into something new, and understand the opportunities to use them. Thinking skills. Calculating in new ways and implementing computational strategies like acquiring any domain [8]. How important is CT in the development of children towards a promising future using the latest thinking and technology? Several colleges across the United States and several countries have reviewed their computer science curricula. The guys there tweaked their first course in computer science, and it was done to cover basic principles and concepts, not just programming.

The illustration above shows the importance of studying learning that can develop students' abilities in the field of CT. The teaching in question is learning using the

STEM approach. The STEM approach will be able to link CT to its education [9]. Therefore, STEM practitioners are expected to be more trained and ready to face complex challenges and problems that will not be solved except with CT.

### 1.1. RESEARCH METHOD

This type of research is a literature study. Researchers conducted searches from various references related to STEM and CT. There are about 30 books/articles that became references in the preparation of this article. We selected papers/books using the keywords STEM (Science, Technology, Engineering, and Mathematics) and Computational Thinking (CT). We did an article search via Google Scholar and e-books. We limit articles published in the last ten years to review. The reports we reviewed were classified as theoretical studies and articles on the results of research on STEM and CT. From our search results, we underlined the primary meanings of STEM and CT in each paper; then, we synthesized these terms to understand STEM and CT. We also synthesized the relationship between STEM and CT. The results of our research are an understanding of STEM and CT, the relationship between the two (in the form of a graph depicting the relationship), and how to develop CT through STEM.

## 2. RESULT AND DISCUSSION

### 2.1. Definition of Computational Thinking Skills

There are several definitions of Computational Thinking (CT) skills. According to Wing [10], Computational thinking is a person's ability to solve problems, design systems, and understand human behavior by drawing concepts in computer science. In addition, computational thinking is the thought process of a person involved in formulating problems and representing the solution in a form that can be carried out by information processing tools effectively [11–13].

PISA 2021 also states that computational thinking includes pattern recognition, designing problems, using abstraction, pattern decomposition, determining computational tools that can be used in analyzing or solving problems, and defining all albums part of a detailed solution. In addition, computational thinking has been described as how students use computers to model their ideas and develop programs. Output computational king has a long history in computer science, known in the 1950s and 1960s as "algorithmic thinking." It means a mental orientation or formulating

problems, converting some inputs to outputs, and looking for algorithms to perform the conversions [13].

Hemmendinger argues that computational thinking teaches a person how to think like an economist, physicist, or entertainer and understands how to use computing to solve their problems, create, and define new questions that can be explored and acted upon [14]. However, there are many different definitions from several experts regarding CT. As a result, there is no clear definition for CT [15]. Nevertheless, according to CSTA (Computer Science Teacher Association) and ISTE (International Society for Technology Education), the following table explains that we can do many things in computational thinking activities.

Table 1: Practical computational thinking activities by ISTE.

| Keywords | Source |
|---|---|
| Formulate, organize, analyze, model, abstraction, algorithmic thinking, automate, generalize, transfer | ISTE 2011 |
| Creativity, algorithmic thinking, critical thinking, problem-solving, collaboration | ISTE 2015 |
| Data analysis, abstract thinking, algorithmic thinking, modeling, data representation | IST 2016 |

### Computational Thinking Components

Some experts mention the existence of CT components such as Abstraction, Algorithm Thinking, Decomposition, Evaluation, and Generalization. The following table presents the opinions of several experts regarding CT components.

Table 2: Components of computational thinking.

| Component | Source |
|---|---|
| Abstraction, Algorithm, Automation, Problem, Decomposition, Parallelization, Simulation | Barr & Stephenson [16] |
| Abstraction, Automation, Analysis Abstraction, Algorithm, Automation, Problem, Decomposition, Generalization | Lee et al [17] Wings [18] |
| Abstraction, Algorithm Thinking, Decomposition, Evaluation, Generalization Abstraction, Algorithm, Decomposition, Debugging, Generalization | Selby & Woolard [19] Angel et al [20] |

Some things that are considered related to components or aspects in computational thinking that some aspects are passed are by introducing patterns, decomposition, algorithms, abstractions, and generalizations or evaluations. The fact is that computing and computer science are not the same things. The end goal is not to teach everyone to think like a computer scientist, but to teach them to apply common elements to solving problems and finding new questions that can be explored within and across all disciplines. Computational thinking does not mean thinking like a computer, but

thinking about computing where one is required to formulate a problem in the form of a computational problem, compile a good computational solution in the form of an algorithm or explain why a suitable solution is not found. Some of the basic skills in CT are spatial abilities, reasoning skills, and problem solving [21]. Based on the study of computational thinking that CT is the ability of students to solve a problem through several stages, namely decomposition, pattern recognition, algorithms, abstractions and generalizations.

## 2.2. STEM Education

STEM is an acronym for Science (S), Technology (T), Engineering (T), and Mathematics (M), all of which are one unit and do not stand alone [22]. STEM learning is learning that integrates science, technology, engineering, and mathematics in problem-solving. With these components, students can use the knowledge gained to solve problems in everyday life under the demands of today's world of work. The purpose of implementing STEM is so that students can count, understand mathematics and science, and apply them in everyday life. However, in general, education conducted by teachers teaches science, not by integrating technology, engineering, or mathematics into their curriculum [23]. Research from the last four years in STEM education demonstrates a balance between academic research and action research for practitioners. Some teachers teach by practicing STEM as a teaching method in the classroom and make it a little research developed by the teacher [24]. One of the studies that have been carried out related to STEM is the Arkansas Cyberinfrastructure Minority Training Education Consortium (AMC-TEC) project which provides a feasibility study on the use of Cyberinfrastructure resources for STEM education [25].

Several factors influence learning with the STEM approach in schools. Some of these factors are internal, and some are external. Internal factors include psychological, physiological, student abilities, interests, and students' talents. External factors include teachers, parents, environmental conditions, and society. If viewed from internal factors, not all students will be able to understand the lesson at the same speed. Many things cause this, such as by various things, such as ethnicity, gender, economic background, student study habits, and also their fighting power [26]. STEM is briefly defined as an interdisciplinary approach to learning where academic concepts are linked to the real world, so that students are able to apply science, technology, engineering and mathematics in the context of life problems.

## 2.3. STEM and CT Relationship

STEM and CT are interrelated. The learning approach that combines Science (S), Technology (T), Engineering (T), and Mathematics (M), known as STEM, has become a topic of international discussion in the last decade. The real benefit of learning using the STEM approach is the integrated student learning outcomes, not only aspects of knowledge in one area but also problem-solving skills in several other areas. Similarly, CT has become an indispensable part of today's needs. Considering the role of STEM and CT in encouraging progress in many fields, it is natural that teachers in schools should carry out learning using the STEM approach for specific appropriate topics. Considering how learning using the STEM approach and how the students can acquire thinking skills from CT, many experts recommend that CT be part of a STEM education program for all ages and students [27, 28]. Integrating computational thinking into the STEM curriculum gives students a more realistic view of how professional STEM scientists function to achieve their research and professional goals. This integration will better prepare students to build knowledge and skills. Therefore, students need to use this computational thinking ability [29, 30]. Wintrop et al. argue that science and mathematics are meaningful contexts in which we can successfully place the concepts and practices of computational thinking. This is because they think that the way mathematicians and scientists use computational thinking skills is to advance their disciplines.

Talking about the reconnection of CT and problem solving, there is some confusion between these two concepts, as one is considered identical or overlapping with the other [31]. This has something to do with STEM that explicitly solves real-world problems. As a result, the curriculum has been changed to include CT activities from primary to secondary schools, and international teacher associations have had to address the need to introduce STEM and CT in education [32–34] It is further reinforced that CT and STEM are naturally connected, as CT skills and STEM education's view of the problem-solving focus on solving transdisciplinary and complex problems in real-world situations [35]. STEM education relates content knowledge to real-world situations, and CT provides a cognitive framework for studying those relationships [36]. This means that the role of CT in implementing STEM education is significant and essential. Vice versa, with STEM, CT can be developed through learning.

### 2.4. Developing CT through STEM

Based on the description above, developing computational thinking skills raises terms associated with CT components and aspects of STEM. The ability to think computationally as a practice of transdisciplinary thinking, this was stated by Yeping et al in their discussion [31]. Computer programs that can be used to make applications require computational thinking skills, where there is a coding process there and it is included in the technology component in STEM. Ptogramming is the main key to teach and learn about computational thinking skills, this can be done in a class with or without a computer. Verbal problems in mathematics such as accounting, the area of the fenced area is basically included in one aspect of CT, namely abstraction. Verbal problems do not escape calculations and pure science, namely mathematics and science. Some of these things can be changed in the form of the Figure 1.

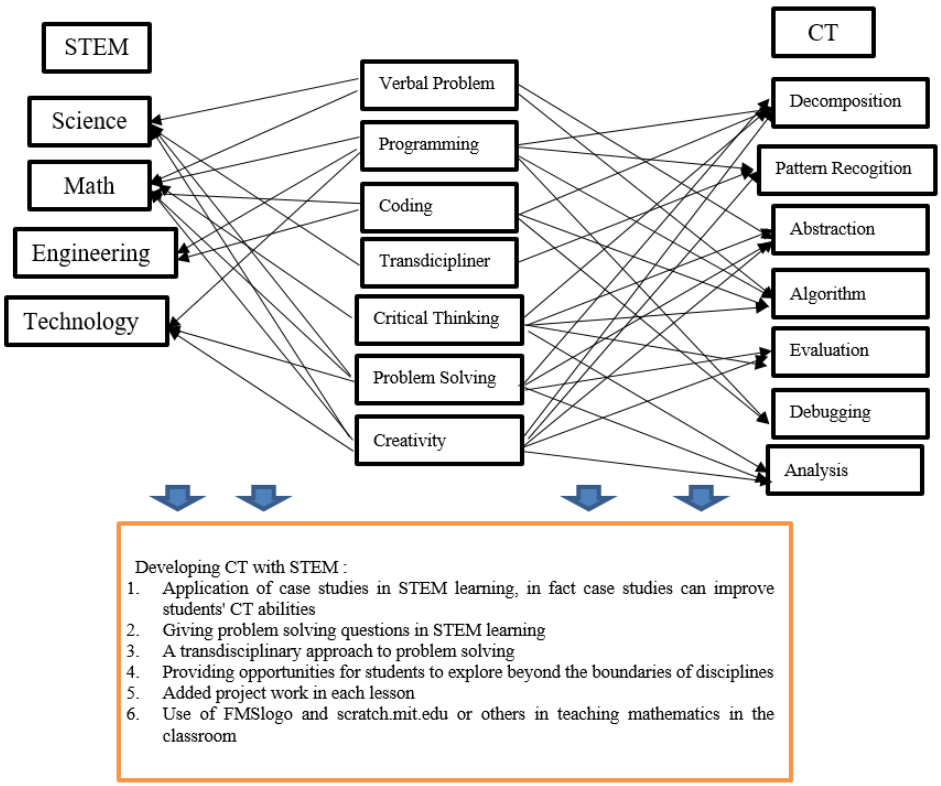


**Figure** 1: Developing CT with STEM.

## 3. CONCLUSION

The picture that shows the relationship between STEM and CT above reinforces the importance of teachers implementing learning with a STEM approach. Especially if the

teacher hopes that his students will be able to succeed in the era of digital technology as it is today. The problems that students will face in the future will be more complex. Therefore, the need to develop student CT is absolute. Based on a study of more than 30 articles and research results related to the effect of STEM on student learning outcomes, we can conclude that learning using STEM has the potential to develop students' computational thinking skills.

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