Integration of Computational Thinking in Mathematics Education in Indonesia

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Abstract. Computational thinking (CT) has attracted the attention of many parties after it was popularized by Wing in 2006 and was determined to be one of the 21st century skills. Various countries, including Indonesia, have begun to respond to the issue by integrating CT into the education curriculum. In 2018, CT be-came the competency of choice at the junior and senior high school levels, only in 2022, CT became a mandatory competency taught in informatics les-sons (junior high school, junior high school) and integrated into learning mathematics (elementary school). The direction of educational policy deter-mines the direction of CT research and development and vice versa. This study aimed to carry out a systematic review of the literature on the integration of CT in mathematics education in Indonesia by focusing on the review of the CT-based learning approach used and the relationship between CT and mathematical thinking aspects. The literature studied was sourced from the Scopus, Eric, and Sinta databases. Of the 1,276 articles collected, by apply-ing the PRISMA protocol, 22 articles were selected that were relevant to the topic and met the inclusion and exclusion criteria. Analysis of the content of the literature focused on the year of publication, type of research, research subjects, CT framework, context, learning approaches and tools as well as the interrelationships between CT and mathematical thinking. Based on the results of the study, it was found that (1) CT integration research had started to be carried out a lot since 2019 using qualitative methods involving elementary school students, (2) the CT-based learning approach used generally with a task structure approach such as PBL and RME, assisted approaches were also found ICT but had not used programming tools, (3) there was a unidirectional relationship between CT and mathematical problem-solving abilities.

Keywords: Computational thinking, mathematics education, systematic literature review

1 Introduction

Since Jeannette Wing conveyed her ideas about CT skills through an article entitled "Computer Science for All" in 2006. The term of CT has returned to popularity and is considered a turning point for the integration of CT in the school curriculum. Declaration about the importance of CT skills started to emerge. CT is used as basic literacy for the 21st century, as well as reading literacy and numeracy literacy [1]–[3]. CT is

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also defined as a future work skill that must be owned by someone to compete globally [4]–[7]. The Organization of Economic Cooperation and Development (OECD) defines CT as a key work skill needed by student to succeed in the world of work. The OECD has included aspects of CT in the 2021 Program for International Student Assessment (PISA) framework as part of mathematical literacy.

The awareness about the importance of CT has been responded positively by various countries that is manifested in the form of inclusion of CT in the education curriculum. CT is made a core literacy in the 2017 Chinese national curriculum [8]. CT and programming are integrated in technology and informatics lessons for elementary, middle and high school levels. In England, the integration of CT has been carried out in the 2014 of curriculum renewal by dividing it into 4 stages, namely stage 1 (5-7 years): students make and correct simple program errors, stage 2 (7-11 years): students design, write and improve the program to achieve specific goals, stage 3 (11-14 years): students are able to design, use, and evaluate computational abstractions, and stage 4 (14-16 years); students are able to develop and apply their analytical thinking, problem solving, design and computing skills [9]. Other countries such as Finland have also integrated CT in their latest curriculum in 2014, Japan has made CT a mandatory component of its curriculum starting from elementary to high school levels since 2020 and while South Korea has started since 2018.

In Indonesia, in the latest curriculum for 2022, namely the independent curriculum, computing thinking has been made mandatory content in the curriculum that is taught in 6 phases from elementary to high school. At the elementary level (phase A, phase B, phase C) CT is integrated into existing lessons, such as mathematics, Indonesian and science, while at the junior high school level (phase D) and high school (phase E, phase F), CT is taught in a special subject, namely informatics. Actually the policy of integrating CT into the Indonesian national curriculum has also been carried out in the previous curriculum, but it is still optional and not mandatory, and is only integrated in Informatics lessons for junior and senior high schools [9]. The efforts to disseminate and educate CT have also been carried out by several non-formal organizations such as Google through the Smart Indonesia Movement, Bebras and TOKI through the Bebras challenge contest that has been held regularly every year since 2016. It shows the excellent attention of the Indonesian government and people on the importance of CT.

The definition of CT cannot be separated from the history. At the first time, this term appeared in the field of computer science, so its definition is often associated with programming activities [10]. Nowadays, CT has been applied to various fields such as economics, biology, physics, chemistry, mathematics and also education. In the field of education, the emphasis on the definition of CT is more on aspects of thinking [11]–[17] even though the definitions of CT are still very diverse. Many experts have defined the notion of CT and the definitions given tend to diverge. Therefore, the writer is interested in knowing the trend of CT frameworks developed in research in Indonesia.

Mathematics and CT have a very close fundamental relationship. Mathematical thinking can enrich CT and vice versa [18]. Mathematical content can be used as a context in learning CT and conversely CT can be used as a tool for solving mathematical problems effectively and efficiently [19]. Integrating CT in the national curriculum, especially in mathematics lessons has been carried out by Finland and France. In Indonesia, the integration of CT in mathematics is required for the elementary school level and is recommended for the junior and senior high school levels. Thus, the tendency of the research into the integration of CT in mathematics learning in Indonesia is important information that needs to be studied. The results of this study are very useful for obtaining an overview and determining the direction of research development and implementation of CT policies in Indonesia.

The results of studies on research trends and the integration of CT have been carried out by many previous researchers. Some of the trends found that : (1) the integration of CT in education is widely applied through programming activities [20] [21]by using learning approaches such as project-based learning, problem-based learning, cooperative learning and game-based learning [21], (2) environment and tools that can improve CT skills, namely graphical programming (scratch, Alice, Game Maker, Kodu, and Green foot), Web-based simulation authoring tools (Agent sheets, Agent cubes) as well as robotic kits and tangible media (Arduino and Gogo Boards) [22], (3) the CT assessment used places more emphasis on programming/computation skills [23], and (4) CT is defined as a way of thinking in solving problems effectively and efficiently that includes 6 aspects of skills namely decomposition, abstraction , algorithm design, debugging, iteration, and generalization [24].

Particularly, studies on the integration of CT in mathematics learning have also been carried out by several researchers and the trend is that (1) the focus of integrated CT activities in mathematics learning is on skills such as sequencing, looping, conditionals, debugging, decomposition, pattern recognition, and abstraction [25] [26], (2) integration is carried out fully, namely by teaching mathematics directly through CT activities [25], (3) more research is carried out by computer experts than education experts[27] and more for the elementary school level with this type of research is dominated by case studies [26], (4) the integration of CT has been widely carried out on the topics of geometry and numbers [26] but is still rarely applied to the topics of probability, statistics, measurements and functions [27], (5) applied learning in the integration of CT, namely student-centered learning [28] and assisted programming tools [26] such as geometricized programming [28], and (6) the form of integration that is carried out is using mathematics to create CT artifacts, interpreting CT output, and generate new mathematical knowledge parallel to the development of CT [28].

Although many studies have been conducted to look at trends in the results of research on the integration of CT in education, including specifically in learning mathematics, none of these research studies has revealed in depth what the research trends are in the integration of CT in mathematics education in Indonesia. It is interesting considering that Indonesia has integrated CT into the national curriculum since 2017, and many studies on the integration of CT in education have been carried out including in learning mathematics, however, there are indications that student achievement of CT mastery is not optimal, one of which can be seen from the low scores and ratings. Indonesian students in PISA. As we all know, the OECD has determined CT as an aspect that is measured in the assessment. Therefore, this study aimed to get an overview of research trends on the integration of CT in mathematics education by answering the following questions.

1. What type of research mostly carried out?
2. What level of education is mostly done?
3. Which aspect of CT skill is mostly used as a CT framework?
4. In what contexts is CT integration research mostly carried out?
5. What learning approaches and tools are used in CT integration?
6. What is the relationship between CT and Mathematical thinking found in the research?

2 Methodology

2.1 Research Design

This research is content analysis research that focuses on the findings of various studies on the integration of CT skills in mathematics education in Indonesia. Content analysis was carried out using the systematic literature review method using the PRISMA protocol [29].

2.2 Browsing Process

The literature search used the SCOPUS, ERIC and SINTA databases

Table 1. Literature Browsing Keywords

Database	Key words
Scopus	TITLE-ABS- (“*CT” AND “mathematics”)*
ERIC	Search “CT” AND “Mathematics”
SINTA	Search “CT” or “CT”

2.3 Selection Process

The inclusion and exclusion criteria are presented in Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Problem/Population	Research topic on the integration of CT in mathematics education in Indonesia	The research topic is not related to the integration of CT in mathematics education in Indonesia
Intervention	Not using interventions, research can be quantitative, qualitative, mix method	Research results of literature review

Criteria	Inclusion	Exclusion
	research and research by practitioners.	
Comparation	There is no comparison factor	There is no comparison factor
Outcome	Explaining the integration of CT in Mathematics Learning	Not related to CT Integration in Mathematics Education
Published Year	2006 - now	Before 2006
Language	English and Indonesia	Beside English and Indonesian

2.4 Data collection

Data were collected from the results of content analysis on writings about the integration of CT skills in mathematics education in Indonesia. All articles were collected from publications in the SCOPUS, ERIC and SINTA databases. The study was only conducted for full text publications that met the inclusion and exclusion criteria.
The instrument used in this research is a guidance in conducting content analysis that contains several aspects as shown in Table 3.

Table 3. Literature Review Framework

Aspect	Category	
Research Methods	1 Quantitative Research 2. Qualitative Research	3. Mix-Method Research
Research subject	1. Early Childhood 2. Primary School	3. Junior HS 4. Senior HS
Aspects of CT Skills	1. Decomposition 2. Abstraction 3. Pattern Recognition 4. Algorithmic Thinking 5. Testing & Evaluating	6. Logical Thinking 7. Debugging 8. Data collection & Analysis Data Representation
Learning Context	1. Mathematics	2. Multidisciplinary
CT Learning Approach	1. Digital-based teaching aids	2. Task Structure
Learning Tool	1. Text based Programing 2. Geometrized Programing	3. Block Based 4. Tangible Programing

2.5 Data Analysis

The selected articles were classified into categories in Table 3. The classification is based on the information contained in the abstract, methods and research results. Furthermore, the data was presented descriptively.

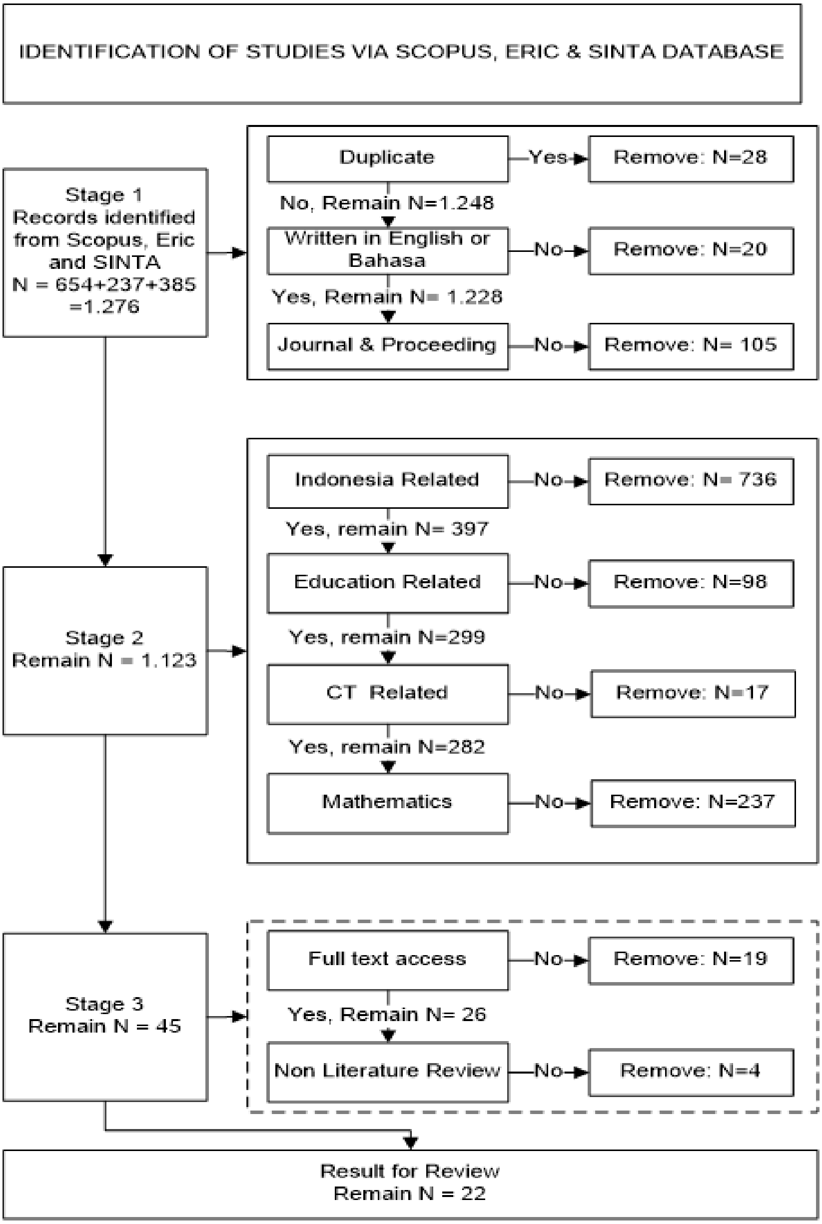

Fig. 1. PRISMA Flowchart

3 FINDINGS

3.1 Publication Review by Publication Year

The results of a literature study related to research on the integration of CT in mathematics education in Indonesia showed that this topic began to be widely researched and published in 2019 and the number continued to increase in the following years.

Table 4. Distribution of Yearly Publication

Year	Frequency
2019	4
2021	8
2022	8
2023	2
Total	22

3.2 Review Based on Research Subjects

The results of the trend analysis of research subjects on the integration of CT in mathematics learning in Indonesia showed that the research tended to involve junior high school students, then high school, and elementary school students. There has no research at the kindergarten level.

Table 5. Distribution of Research Subjects per Level

Level	Total
Pre-School	0
Elementary School	3
Junior High School	9
Senior High School	4
College/University	6
Total	22

3.3 Types of CT Research in Mathematics Learning

Research on the integration of CT in mathematics education in Indonesia is mostly in the form of non-intervention research, namely in the form of qualitative research with a descriptive and phenomenological design. Other types of research carried out were development research, DBR and experiments, but in small quantities.

Table 6. Distribution of Research Types

Research Type	Total	Description
Quantitative	1	Experiment
Qualitative	15	Descriptive (13)
		Phenomenological (2)
Mix Method	6	R& D (4)
		DBR (2)
Total	22	

3.4 The Context of CT Integration in Mathematics Learning

Mathematics and CT has a very close fundamental relationship. Both had a mutually reinforcing relationship, namely mathematics can enrich CT and conversely CT can strengthen mathematical abilities [30]. Mathematical content can directly be used as a context in developing aspects of CT. Mathematics content is often combined with other disciplines such as science, technology, engineering and art or also known as STEAM, the integration of CT in STEAM that is not only specific to mathematical content has also attracted the attention of several researchers in Indonesia. Some examples of CT integration in mathematics that have been carried out are algebra, geometry and numbers. The results of the article review showed that the context of integration of CT in Indonesia was mostly monodisciplinary (mathematics) rather than multidisciplinary. The most researched math topics were geometry, numbers and algebra.

Table 7. CT-Based Learning Context

Context	Total	Description
Multidisciplinary	4	STEAM
Mathematics	18	Algebra (2)
		Geometry (4)
		Number (3)
		NA(9)
Total	22	

3.5 Review Based on the CT Framework

Many experts try to provide a definition of CT by explaining the aspects in more detail. Of the 22 articles reviewed, 17 of them referred specifically to existing definitions. The table below showed that research on the integration of CT in mathematics education in Indonesia referred more to the definition of CT by Jeannette Wing and the definition of CT listed in the guidelines for implementing the Indonesian national curriculum from the Ministry of Education and Culture.

Table 8. CT Framework

Source	Aspects of CT Capability	Total
Wing (2006, 2008, 2011)	AAADDG Abstraction, Algorithm, Automation, decomposition, debugging, generalization	6
ISTE and CSTA (2011)	Formulation, logical organization and analysis of data, abstraction, algorithm, generalization	2
Bacconi *et al* (2016)	3D Concept, Practice, Perspective	1
Kemdikbud, Google: *Gerakan Indonesia Pandai*, BBC	AADP Abstraction, generalization, algorithm, pattern recognition, decomposition	6
TOKI (2018)	Decomposition, abstraction, pattern recognition, data representation, algorithms	1
Bebras [31]	Decomposition, Pattern recognition, Abstraction, Modeling-simulation, Algorithms, Evaluation	1
Own Definition	Decomposition, Data representation, Pattern recognition, Algorithmic reasoning, Generalization, Evaluation	1

3.6 Learning Approach Used

In the research conducted by [28] classifies the CT-based learning approach into 2 major groups, namely task structure and other structure. The results of the literature analysis showed that the integration of CT in mathematics education in Indonesia used more task structure approaches such as the realistic Mathematics Education (RME) approach, Problem Based Learning (PBL), Rigorous Mathematics CT (RMCT) and also scaffolding techniques.

Table 9. CT-Based Learning Approach

Approach	Total	Description
Task Structure	6	RME approaches (2)
		PBL (2)
		RMCT
		Scaffolding Technique
Other structure	4	e-module based learning
		digital-based teaching aids
		web-based mathematics lessons/computers.
		interactive digibook
Total	10	

3.7 Programming Tools Used

The most widely used programming tool in developing CT in mathematics learning is coding programming, [32], that is also categorized as screen-based programming by [28]. Furthermore [28] also reveals that programming tools can also be in the form of Tangible programming in the form of programming aids in the form of concrete objects that can be manipulated, for example KIBO Robot, Bee-bot Robot, Botley and Cubetto [33]. The results of the analysis of research literature in Indonesia showed that both text-based and tangible programming tools had not been widely implemented in CT-based learning.

3.8 The Relationship between CT and Aspects of Mathematical Thinking

Mathematics and CT have a very close fundamental relationship. Both have a mutually reinforcing relationship, namely mathematics can enrich CT and conversely CT can strengthen mathematical abilities [30]. The results of the literature review showed that there was a unidirectional relationship between CT and mathematical problem-solving abilities. Ct can also facilitate the development of mathematical critical thinking.

Table 10. The Relationship between CT and Aspects of Mathematical Thinking

Aspects of Mathematical Thinking	Total	Description
Critical thinking	1	CT integration can facilitate students in developing mathematical critical thinking
Problem Solving	4	There is a direct relationship between problem solving ability and CT
Total	5	

4 DISCUSSION

The policy of integrating CT into a country educational curriculum greatly influences the direction of research conducted by experts/practitioners in the country. Although the integration of CT in education was first echoed in 1980 by Papert [10] and popularized in 2006. The results of the study showed that the research trend of integrating CT in mathematics education in Indonesia only emerged in 2019. It is allegedly due to the emergence of CT policies in a new Indonesian curriculum appeared in 2018 through Permendikbud Number 36 of 2018 that made CT the elective competency through Informatics lessons [34]. The issuance of this regulation becomes a trigger for researchers and mathematics practitioners in Indonesia to study the integration of CT in mathematics education. The type of research conducted in Indonesia is still dominated by qualitative research in the form of descriptive and phenomenological research, this trend is different from the global trend of CT integration research in mathematics education that tends to use quantitative methods such as quasi-experiments and experiments [35].

In the 2022 Indonesian curriculum policy, CT is defined as a minimum competency that must be mastered by students who are taught from elementary to high school [36]. CT is taught in the compulsory subject of informatics for junior high and high school levels, but for the elementary level, CT is integrated in mathematics, science and Indonesian [37], [38]. The findings in this study showed that CT integration research in mathematics education mostly involved junior high school students then tertiary, high school and elementary school students. There has been no research conducted in preschools. This trend is different from the findings of studies [28], [35], [26] that found that the global trend of CT integration research was mostly carried out at the elementary level. The demand for research products on the integration of CT in mathematics learning in elementary schools in Indonesia is now a necessity considering that the government has required elementary teachers to integrate CT in mathematics learning. Some facts on the ground showed that teachers still really need professional development so they will be better prepared to carry out CT-based learning [39], [40].

Since Papert defined CT in 1980, then Wing modified it in 2006, the definition of CT has evolved. Experts and practitioners in various fields tried to limit CT. Basically the definition of Ct that is currently developing can be grouped into two namely the definition of CT that relates to aspects of the ability to think apart from technology and the definition of CT as a problem-solving method using technological assistance. The CT framework used in mathematics education research in Indonesia tends to view CT as a thinking ability that is independent of technology. The most widely referenced CT framework is from 2 sources such as the CT definition from Wing that includes 6 aspects of skills, namely abstraction, algorithms, automation, decomposition, debugging, and generalization as well as the CT definition listed in the national curriculum guide that emphasizes 4 aspects of thinking, namely abstraction, generalization, algorithm, pattern recognition, and decomposition. The results of the study of global trends on the tendency of the aspects of CT skills that are most widely used in mathematics education research were testing and debugging (54.76%), decomposition (38.10%), abstracting (16.67%), and being iterative and incremental (14.29%) [41].

If we compare it with the aspects of CT skills that are the emphasis in Indonesia, the result is that the emphasis is more on abstraction, decomposition, algorithms, automation, pattern recognition, debugging and generalization skills. In several aspects. it has shown the same trend except for the aspect of being iterative and incremental.

Mathematics and CT have a mutually reinforcing relationship namely mathematics can enrich CT and conversely CT can strengthen mathematical abilities [30]. The relationship between the two is also reaffirmed by [19] who views that mathematics can be used as a context in CT learning and vice versa. Related to the research in Indonesia, a pattern is found that that mathematics is used as a monodisciplinary context rather than multidisciplinary (e.g., STEAM). The learning topics most widely studied in research in Indonesia are geometry, numbers and algebra. The results of a study conducted by [26] shows the same thing. The scope of school mathematics material that is rarely researched is statistics, relations and functions. CT integration in mathematics learning can facilitate the development of mathematical thinking [29], [39], [42]. In this study it was found that CT can facilitate mathematical critical thinking skills. CT has a strong unidirectional relationship with problem solving ability.

5 Conclusion

Based on systematic literature review, it can be concluded that several things related to the integration of CT in mathematics education in Indonesia are as follows. (i) Research on the integration of CT in mathematics education starts to be carried out in 2019 using qualitative research methods in the form of descriptive research and phenomenological research. (ii) Research on the integration of CT in mathematics education mostly involve junior high school students, followed by tertiary education, high school and elementary school. There are no research publications at the preschool level. (iii) The most widely used definition of CT is the definition of Jeannette M. Wing and the definition of the Ministry of Education and Culture. (iv) CT is more integrated in the context of mathematics compared to multidisciplinary. The most researched math topics are geometry, numbers and algebra. (v) The approach used in CT-based learning is a task structure approach in the form of PBL and RME implementation. ICT-assisted research has also been carried out but the use of programming tools has not been found. (vi CT has a direct relationship with the ability to solve mathematical problems. CT can also facilitate the development of mathematical critical thinking skills.

6 Recommendations

From some of the findings obtained through this study, there are several follow-ups that can be carried out in research on the development of CT through mathematics education. The type of intervention research is still very rarely carried out in an effort to test the effectiveness of an action to develop aspects of CT and mathematical thinking. The research conducted should target elementary school students so that it is in line with the government policy that requires the integration of CT in mathematics learning.

Mathematics topics that are rarely researched consisted of probability, statistics, relations and functions. The intervention can be in the form of a programming-based learning approach with the help of block-based programming. It is expected that there will be more research products on the integration of CT in mathematics education so that it can be used as a reference in efforts to develop CT in schools.

7 Limitations

It needs the caution in drawing conclusions because there are limitations in the research findings obtained from selected review articles that may not be representative.

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