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**Submission date:** 20-Mar-2024 04:33PM (UTC+0300)

**Submission ID:** 2325746271

**File name:** SLR\_ENGLISH\_CT.docx (349.04K)

**Word count:** 6699

**Character count:** 40547

## Computational Thinking in Mathematics Education: A Systematic Literature Review on its Implementation and Impact on Students' Learning

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### A. Introduction

Within the early 19th century, the term "computational considering" developed in association with the utilization of subjective examination in science and came afterward in association with the emphasis on thinking within the instructing of number juggling (Childs, 2015). As we enter the mid-21st century essential computational considering aptitudes are basic for people of all ages (Kalelioğlu et al., 2016; Wing, 2014). Computational considering is utilized as one of the approaches to create problem-solving aptitudes (Afifah & Kusuma, 2021). Computational considering alludes to a joining of problem-solving stages comprising of thoughts, openings, and challenges confronted to create an arrangement that will be chosen (Fajri et al., 2019). This way of considering, like problem-solving calculations began in computer science but can be connected to other disciplines, particularly arithmetic (Cahdriyana & Richardo, 2020). Helsa et al., (2023) uncovered that computational thinking can moreover be coordinated into math, science, social, dialect, and craftsmanship.

Arithmetic is closely related to computational considering since it includes designs, issue structures, and factors that can be utilized with diverse values. Computational considering abilities have four fundamental components, specifically decay, design acknowledgment, deliberation, and calculations (Kidd & Morris, 2017). Decay is the method of lessening complex issues into basic issues (Cansu & Cansu, 2019). The marker of design acknowledgment is inventively recognizing likenesses or contrasts that exist in an issue so that it can make a person's basic and imaginative considering time more proficient in case this arrangement is continuously familiarized. The reflection pointer is a movement to see the issue as an entire or can be translated as an ability that minimizes the complexity of unimportant qualities in a substance and replaces traits that have comparative capacities with a single development of the substance and replaces properties that have comparable capacities with a single development so that it is simpler to discover an arrangement (Cansu & Cansu, 2019). Reflection can also be utilized to form issues or frameworks

simpler to think approximately (Cansu & Cansu, 2019). At last, the calculation marker is the organization of elective and viable steps to unravel an issue.

Computational consideration is basic within the learning handle. This is often to bolster high-level tackling abilities (Tim Penyusun Materi ITB, 2020). Instructing computational thinking can be deciphered as an educator instructing understudies to think and fathom issues like a computer. In expansion, CT is additionally related to inventiveness and development (Mishra & Yadav, 2013; Reppenning et al., 2015). A few nations have actualized computational considering in their educational modules, for case in Indonesia computational considering has been actualized since 2018. In Permendikbud number 37, the government made computational considering one of the aptitudes that must be had by students at the basic and auxiliary school levels. CT integration in learning has been exhausted in a few nations, such as Australia (Falkner et al., 2014), United Kingdom (Brown et al., 2014), Finland (Mannila et al., 2014), Sweden (Kilhamn & Bråting, 2019), and the United States (Fisher, 2016).

With increasing nations' coordination computational consideration into their educational program, there's a developing number of investigations on this issue. Numerous analysts raise this issue because computational thinking could be an unused thing within the world of investigation and the pointers in computational considering are curious to ponder. The subject of computational considering is related to a few aptitudes such as algorithmic considering, agreeable considering, inventiveness, basic considering, and issue fathoming. One of the articles that examines the relationship of the over points with CT is the article of Doleck et al., (2017).

Indeed, even though CT is still generally modern in instruction, it is pivotal to explore how CT qualities can be created and fittingly executed in formal instruction settings by first conducting a precise writing audit (SLR). SLR may be a strategy for gathering all fabric that's accessible based on predetermined guidelines in arrange to solve a specific inquiry about the issue (Gough et al., 2017). Moreover, SLR could be a deliberate and correct way to classify, select, and assess diverse investigative papers or ponders records (Tikito & Souissi, 2019). When compared to conventional writing, precise inquiry can upgrade audit legitimacy, unwavering quality, replicability, and consistency (Xiao & Watson, 2019). An intensive audit can shed light on the authors' claims of exactness by indicating any crevices and proposing regions for future consideration.

## B. Methodology

The reason for this thought is to accumulate, assess, and compile observational proof almost CT and its effect on SLR-based arithmetic learning. We inspected nine articles that inspected the impact of CT on math learning from the Scopus database. Utilizing orderly and particular strategies, the SLR method surveys clearly expressed concerns in arranging to distinguish, select, and evaluate exceedingly significant investigations as well as accumulate and analyze information from inquires given in insightful diaries (Juandi, 2021). Agreeing with Kitchenham et al., (2009), applying SLR can offer solid planned points of interest to upgrade future inquire about endeavors based on the conclusions given by prior work. We balanced this survey prepare to meet our system, but it still takes after Kitchenham et al (Kitchenham et al., 2009) proposals. The stages of this SLR usage for the most part include three fundamental components: results, improvement, and arranging. Each stage's specifics are shown in Figure 1.

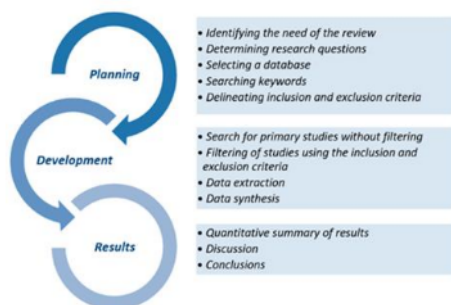


Figure 1. Phase diagram of SLR (Pahmi et al., 2023)

### Planning

The primary arranges in this consider was arranging. An audit method was created that served as a direct for looking into and deciding the goals, strategies and key results of intrigued for the SLR. In this stage, catchphrases, inclusion-exclusion criteria of the inquire about questions (RQ) were decided. The watchwords were utilized for looking on the Scopus database. The comes about found 42 articles based on the watchwords: "computational thinking" AND "mathematics" OR "mathematics education" OR "learning mathematics". Inclusion-exclusion criteria were set to rearrange the method of selecting suitable writing.

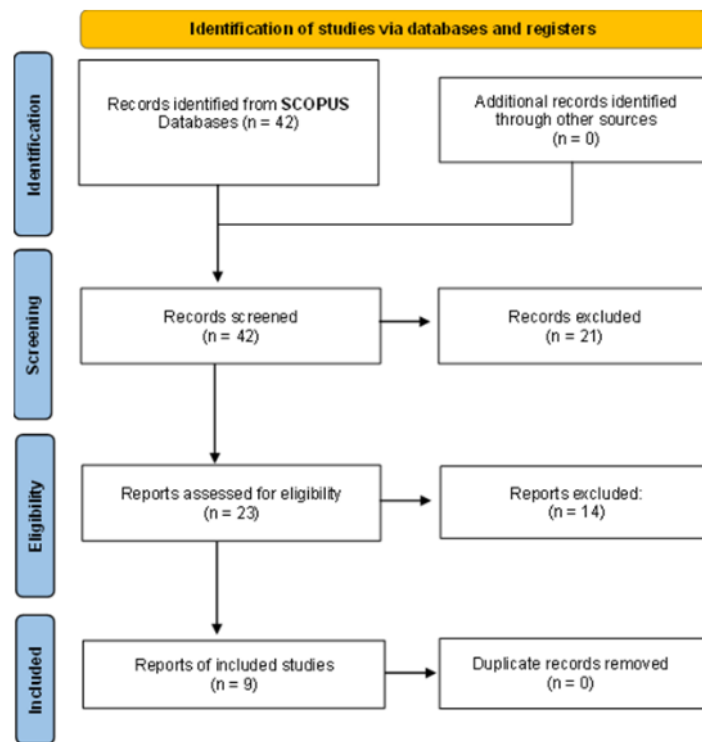
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Table 1. Inclusion-Exclusion Criteria

Criteria	Inclusion	Exclusion
Article title and content	an appropriate title that complied with the study's requirements	did not match the requirements of the study and had an irrelevant title
Year of publication	publications from 2019 to 2023	publications outside the range specified
Type of publication	solely for journal articles	reviews, editorials, and non-empirical studies
Language	English	others
Field of article study	mathematics education	others than mathematics education
Accessibility	full-text articles or open access	preview articles and required a payment

5 These criteria will later determine the literature that will answer the RQ. RQ is the cornerstone of SLR research. RQ is used to guide the process of searching and extracting literature. Data analysis and synthesis are obtained from the SLR results which are answers to the RQ that we have determined. The RQ formula is presented in Table 3.

### Development

The arrange utilized after arranging is the improvement arrange. The advancement organize could be a arrange that contains the execution of an SLR. At this arrange we allude to the Favored Detailing Things for Efficient Surveys and Meta-Analyses (PRISMA). PRISMA makes a uniform peer survey strategy that uses a list of best hones to assist standardize the quality and reproducibility of the amendment process (Conde et al., 2020). Distinguishing proof, screening, qualification, and consideration are the essential components of PRISMA. The stream of this PRISMA convention is appeared in Figure 2.



**Figure 2. PRISMA Protocol Flow Picture**

## Result

The ultimate organizes of this SLR inquire about includes methodological examination and talk of the detailed comes about based on the RQ raised, driving to an SLR conclusion. The SLR investigate moreover gives data on encourage examination related to patterns, consider inadequacies, and recommendations. This arrange will too precisely assess the significance of each stage appeared in Figure 1 and highlight the methodological limitations inalienable within the SLR.

## C. Result and Discussion

This study uses articles collected from the Scopus database as mentioned in the methodology section. Scopus database was chosen because it fulfills the protocol requirements and allows researchers to filter based on a certain time span. As shown in Figure 2, the use of keywords allowed us to retrieve 42 articles from the Scopus database. Due to the application of the inclusion criteria, all the articles were met, so the number of articles remained at 42. After reviewing, 'title, keywords, abstract, and content', 23 articles were published as they met the

requirements within the scope of 'mathematics education'. Finally, 9 articles were selected that met the RQ criteria and will be further analyzed and reviewed. The following articles were used to analyze the information in Table 2.

**Table 2. Author, Article Title and Year of Publication**

Author (Year of Publication)	Article Title
Maharani et al., (2019)	Problem Solving in The Context of Computational Thinking
Reichert et al., (2020)	Computational thinking in K-12: An analysis with mathematics teachers
Soboleva et al., (2021)	Formation of Computational Thinking Skills Using Computer Games in Teaching Mathematics
Bråting & Kilhamn, (2021)	Exploring the intersection of algebraic and computational thinking
Tan et al., (2021)	Exploring the Effectiveness of STEAM Integrated Approach via Scratch on Computational Thinking
Rich et al., (2022)	Computational thinking practices as tools for creating high cognitive demand mathematics instruction
Ng et al., (2023)	Exploring computational thinking as a boundary object between mathematics and computer programming for STEM teaching and learning
Looi et al., (2023)	Exploring Computational Thinking in the Context of Mathematics Learning in Secondary Schools: Dispositions, Engagement and Learning Performance
Sala-Sebastià et al., (2023)	Didactic–Mathematical–Computational Knowledge of Future Teachers When Solving and Designing Robotics Problems

based on the PRISMA arrange, all articles (n = 9) will be analyzed to assemble the data required to reply this investigate address, so that the targets in this SLR inquire about can be accomplished based on the discoveries and realities. The discourse in this consider will be categorized into 5 concurring to this inquire about address. Table 3 underneath gives the answers to the inquire about questions postured and the inspiration behind the investigate questions.



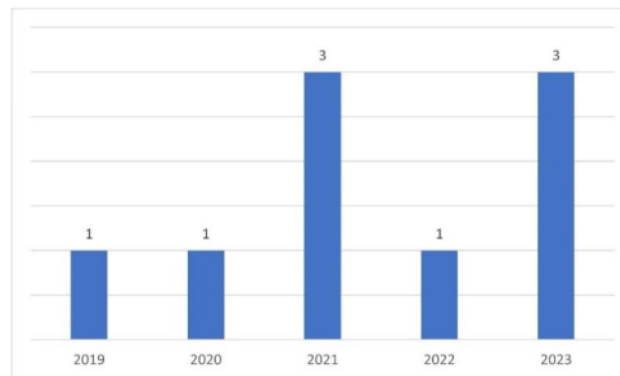
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Table 3. Research Questions

Code	RQ	Motivation
RQ1	How has CT progressed in math learning by year and demographic?	Knowing the year and socioeconomics will give an diagram of the improvement of CT considers that have been conducted and utilized as prescient fabric and those that will be conducted.
RQ2	What research approach was used in the CT study?	This research will provide an overview of the types of research that have been conducted related to CT
RQ3	Who are the research subjects in CT research?	This research provides an overview of the CT research subjects that have been conducted
RQ4	What is the CT research focus of the study?	Provide insight into the focus of CT research studies and serve as a basis for further research
RQ5	What is the impact of learning mathematics integrated with CT?	Provides insight and knowledge on the impact of CT learning integrated in mathematics learning.

based on the Scopus database distributed between 2019 - 2023 related to CT in arithmetic instruction. Figure 3 appears the dispersion of articles analyzed based on the year of distribution based on the researcher's discoveries, CT inquire about in arithmetic instruction has changed based on the Scopus database. It was famous that in 2019 and 2020 the number of articles distributed was 1 article. In 2021, alongside the improvement of CT in science instruction, this investigate has expanded, specifically 3 articles. Be that as it may, in 2022 it diminished, to be specific as it were 1 article. At last, in 2023 it expanded once more, specifically 3 articles. The advancement of CT investigate in arithmetic instruction has varied since the consideration given to the productivity of programming learning plans that utilize CT is still missing (Grover & Pea, 2017; Lye & Koh, 2014). Polat et al., (2021) recommend that further research on CT in arithmetic instruction ought to be conducted within the future to compare the real effect of CT on math problem-solving aptitudes. Combining information and innovation will be the arrangement to the issue (Voskoglou & Buckley, 2012). In this manner, the improvement of CT investigates and the arrangement to illuminate the issue is to actualize the integration between CT and educational modules (Bower et

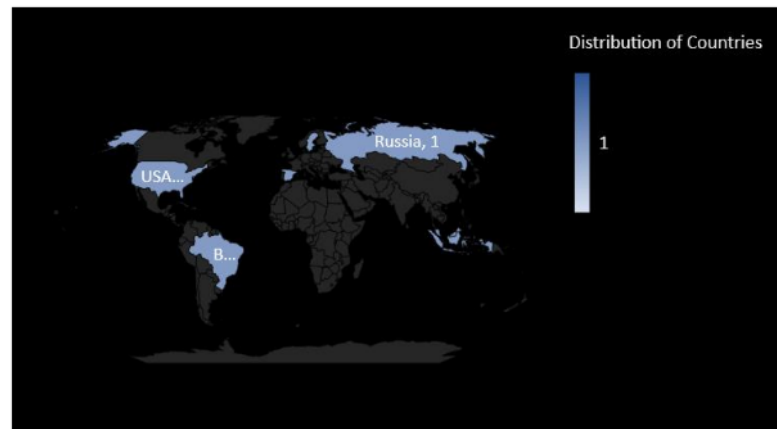


al., 2017; Geary et al., 2000; Voogt et al., 2015; Weintrop et al., 2016) as has been drained Asian nations, Hong Kong, Taiwan, and China (Subramaniam et al., 2022).



**Figure 3. Distribution of Articles Based on Year of Publication**

CT will continue to develop in mathematics education including in the scope of education. The development of CT is important in education because CT and mathematical habits of mind can be linked instructionally (Pei et al., 2018; Weintrop et al., 2016). Good CT skills are one of the things to support higher-order skills (Tim Penyusun Materi ITB, 2020). The fluctuating development of CT in the 2019-2023 timeframe is due to several things. One of the causes of fluctuations is because in the 2019-2022 period, the world is experiencing a Covid-19 pandemic so that the tendency of researchers at that time is technology-based research, such as Augmented Reality (AR) research which is widely carried out (Eldokhny & Drwish, 2021). Regarding the distribution of CT studies by country, Figure 4 shows the publications of selected studies based on the country in which they were conducted.

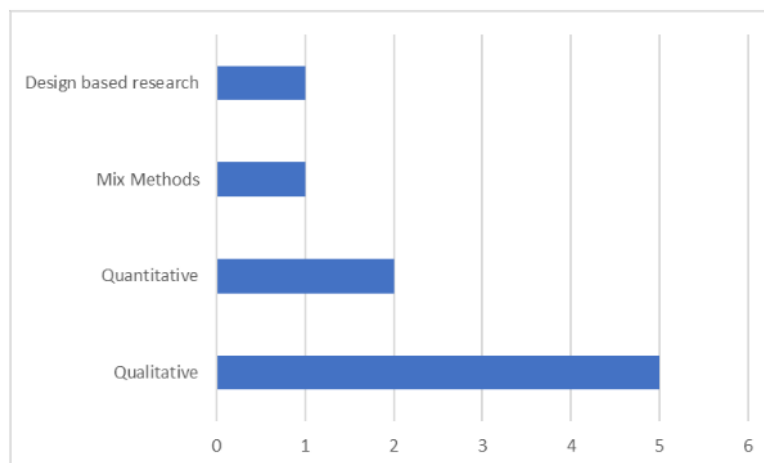


**Figure 4: Distribution of Countries by Research Site**

Based on the data, it was found that there were 9 studies with 9 different research sites. The 9 countries are Indonesia, Brazil, Russia, Sweden, Malaysia, the United States, Hong Kong, Singapore, and Spain with each having 1 article. These countries illustrate that CT research has developed in these 9 countries.

### CT RESEARCH APPROACHES

CT research analyzed in this study has varied research approaches. The differences in research approaches used are due to differences in research objectives carried out by researchers. Figure 5 shows the type of research used.



**Figure 5: Types of CT Research**

Based on Figure 5, qualitative research is the most common type of research in CT research in the field of mathematics education with 5 articles. CT research with a qualitative approach is widely carried out because CT research allows researchers to conduct descriptive analysis based on CT indicators (for example: Helsa et al., 2023; Safitri et al., 2023). The research that uses this type of research is research Bråting & Kilhamn, (2021); Maharani et al., (2019); Reichert et al., (2020); Rich et al., (2022); dan Sala-Sebastià et al., (2023).

Then, CT research with a strong quantitative approach as many as 2 articles. Researchers may use this research approach to see the implementation of school mathematics programming that currently interacts with thinking and learning algebra (Bråting & Kilhamn, 2021), and look at the exploration of relationships between teachers in schools to integrate computational thinking (CT) practices (Rich et al., 2022). Finally, CT research that uses design-based research and mixed methods approaches has 1 article each. Research that uses design-based research is research by Ng et al., (2023), while mix .methods are research Looi et al., (2023). The variety of research approaches used indicates that CT studies are very interesting to study.

### **Research Subject**

CT investigate employments a few distinctive inquire about subjects custom-made to the targets of each ponder. In this think about, the investigate subjects comprised of understudies, understudies, and K-12 arithmetic instructors. Inquire about that employments understudy inquire about subjects is inquire about Maharani et al., (2019), and Soboleva et al., (2021). Not as it were understudies, understudies are moreover utilized as investigate subjects related to CT. Understudies analyzed in CT investigate comprise of understudies from review 1 to review 9. CT must be studied in students since it could be a essential capacity of understudies in instruction since it is related to perusing, composing and checking (Hu, 2011; Zhong et al., 2016). Utilizing CT in learning can offer assistance understudies to memorize to think dynamically, algorithmically, and consistently and be prepared to fathom complex and open-ended problems (Maharani et al., 2019). The procedure that can be utilized is to utilize activity-based learning to assist adolescents' cognitive development, and can offer assistance their learning viably through genuine control and (Cho & Lee, 2017).

Finally, research related to CT used K-12 mathematics teachers as the research subjects. The only research that uses K-12 teachers as research subjects is the study of Reichert et al., (2020). The application of CT ideas and programmatic teaching in K-12 schools can be found in national

and international programs and initiatives (Barr & Stephenson, 2011; Guzdial, 2008; Haseski et al., 2018; Kong et al., 2022) thus, the selection of K-12 mathematics teachers as research subjects was feasible. Sanford & Naidu, (2016) revealed that thinking about CT <sup>4</sup> does not come naturally and requires guidance and training so that qualified teachers to build CT in the future are needed. Therefore, in the future there needs to be research conducted to build CT skills in teachers, especially K-12 teachers.

### **CT Research Focus**

This study also examines the focus of CT research studied in each literature. The focus of the reviewed research is important to discuss because it provides an overview and direction of CT research in the future so as to create novelty in CT-related research. In this section, the author reviews the research focus based on the research approach used.

Investigate Maharani et al., (2019) utilized a subjective approach as a investigate approach by raising the subject of uncovering the relationship between issue tackling and respondents' computational considering when fathoming issues. His research states that there's a relationship between issue solving and computational considering when characterizing issues within the context of issue fathoming, respondents do the deterioration and reflection stages within the setting of computational considering. It is imperative to raise this subject since scientific considering plays an critical part <sup>13</sup> in CT (Gadanidis, 2017; Rambally, 2017; Son & Lee, 2016) numerical issue tackling is basically a development prepare <sup>9</sup> (Benakli et al., 2017; Junsay, 2016; Lockwood et al., 2016).

In spite of the fact that utilizing the same approach as investigate Maharani et al., (2019) investigate Reichert et al., (2020) raised diverse themes, to be specific the introductory recognition of computational considering in a gather of K-12 science instructors, assessing the commitment of proceeding instruction courses in science subjects, and examining conceivable changes in educating strategies. CT inquire about in K-12 is significant to consider since the educational programs that's as of now being created as of now emphasizes CT, for case in Brazil. More particularly, at the basic school organize the term CT is related with the particular competencies and topical unit <sup>2</sup> "Variable based math" in mathematics, which states that learning variable based math, number, geometry, and likelihood and statistics can contribute to the advancement of students' computational considering (BRAZIL, 2018).

Inquire about Bråting & Kilhamn, (2021) moreover employs a qualitative approach by raising the subject of examining how the current usage of school science programming interatomic with logarithmic considering and learning. The examination utilized is based on Duval's semiotic representation hypothesis, to be specific by implies of the language structure and semantic of the programming dialect harmonized from the comparing arithmetical imagery. The comes about uncovered that in spite of the fact that the semiotic representation of programming dialects is comparative to logarithmic documentation, the meaning of diverse concepts in these two spaces is diverse, so in a learning viewpoint, these contrasts must be considered. This investigate emphasizes that utilizing computers as a apparatus to instruct variable based math is supportive, but can lead to errors in the event that programming presents other implications of language structure (Qian & Lehman, 2017), and this could have an effect on learning algebra.

Investigate Rich et al., (2022) too utilized a qualitative approach as the investigate approach utilized by raising the subject of investigating the relationship between the endeavors of two basic school instructors to coordinated computational considering (CT) abstraction, debugging, and decomposition into science educating and the advancement of their high-level tasks. It is critical to raise this subject since the integration of computational considering at the essential school level in mathematics teaching is one of the strategies that can be utilized to present primary school understudies to computer science thoughts (Gadanidis et al., 2017; Israel et al., 2015; Rich & Yadav, 2020). At long last, CT inquire about those employments a subjective approach is that of Sala-Sebastià et al., (2023) with the subject of characterizing the highlights of didactic-mathematical and computational information of imminent kindergarten instructors displayed when fathoming and posturing mechanical autonomy issues. Mechanical technology issues are utilized to familiarize understudies with algorithmic considering in an exertion to create students' CT abilities.

Subjects raised utilizing this sort of quantitative approach are moreover curiously to think about in inquire about related to computational considering, for illustration investigate by Soboleva et al., (2021) raised a point related to instructive computer recreations as an action in student arithmetic and this may move forward the quality of arithmetic educating in advanced schools in supporting the improvement of students' computational considering aptitudes. What is curiously approximately this subject is that instructive amusement spaces ought to be utilized as openings to



spur Era Z learning, empower cognitive exercises and create students' systemic and critical considering (Ilomäki & Lakkala, 2018).

Subjects raised by Soboleva et al., (2021) is distinctive from the subject raised by Tan et al., (2021) in spite of the fact that both utilize a quantitative approach. Inquire about Tan et al., (2021) centers more on things related to the adequacy of the STEAM (Science, Technology, Engineering, Art, Mathematics) coordinates approach through Strach on five subconstructs of computational considering (CT) including algorithmic considering, participation, imagination, basic considering, and problem-solving abilities. The integration of CT in STEAM interdisciplinary instruction may be a modern point (Li, 2018; Li et al., 2020). Combining the five disciplines into one subject without compromising the quality and learning targets of the lesson may be a challenge (Conde et al., 2019). In this manner, this investigate topic is exceptionally curiously to be considered assist within the following CT-related investigate.

There are also computational considering thinks about that utilize design-based-research as the chosen approach, for illustration the ponder of Ng et al., (2023) raised the subject of a student's work being inspected and at that point analyzed whereas locks in in numerical issue understanding in a programming environment, taking CT as a boundary protest implanted in a block-based programming environment, strach. The discoveries in his think about open a unused measurement that explores CT as a boundary question in an coordinates STEM (Science, Technology, Engineering, Mathematics) instructional method.

At long last, research Looi et al., (2023) utilized blended methods as the chosen approach. Their investigate raised topics related to creating CT-integrated science learning that combines issue fathoming and CT-focused modeling in arithmetic instruction investigate.

### **Impact of CT-Integrated Mathematics Learning**

Within the past segment of this investigate audit, a few subjects that can be raised in CT-themed inquire about were revealed. In this area, we'll examine the effect of the usage of joining CT in arithmetic learning. The execution of CT-integrated science learning gives benefits for understudies to be commonplace with computer science thoughts (Gadanidis et al., 2017; Israel et al., 2015; Rich & Yadav, 2020) since CT can be presented since elementary school. CT advancement does not come normally and ought to be created early.

Joining CT in learning can be through instructive diversions as done by Soboleva et al., (2021). The benefits that can be felt by understudies incorporate: spurring Era Z learning,



empowering cognitive exercises and creating students' systemic and basic considering (Ilomäki & Lakkala, 2018). In this manner, it is vital to plan and create extend instructive diversions since they will learn how to utilize computers to illuminate math issues, connected errands, and make educated choices utilizing computerized assets. Not as it were through instructive recreations, Bråting & Kilhamn, (2021) uncovered that CT improvement can too be done by doing a arrangement of programming exercises. The programming exercises carried out can create students' CT so that there are 3 programming exercises suggested for arithmetic. CT moreover has an effect as a question that can interface science and computer science in the setting of school issue understanding (Ng et al., 2023).

At that point, CT capacity moreover has an effect on issue fathoming capacity, particularly when characterizing issues within the setting of issue fathoming, respondents do the decomposition and deliberation stages within the setting of computational thinking. This happens since a person's CT considering includes a relationship with students' problem-solving capacity (Maharani et al., 2019). Not as it were that, the impact felt by understudies through the STEAM approach through the electrical concept diversion plan extend moreover includes a noteworthy impact on expanding CT within the five understudy CT subconstructs (Tan et al., 2021) such as: algorithmic considering, participation, inventiveness, basic considering, and problem-solving abilities.

The effect of CT moreover be seen from an educational modules point of view, where CT can be utilized as a learning introduction to back instructors in arranging tall quality science instruction (Rich et al., 2022). In this case, CT acts as a curriculum-stage methodology (Taylor, 2016). CT introduction utilized in learning can make learning significant.

CT moreover has an impact as a considering apparatus included in defining issues so that their arrangements can be spoken to as computational steps and calculations (Sala-Sebastià et al., 2023). Finding the correct computational show is an imperative portion of this prepare (Aho, 2012). At long last, the impact of coordination CT within the mathematics learning prepare is that CT miens can increase students' engagement in a roundabout way such as expanding self-confidence to an exceptional level by making them more able to work difficult and pay more consideration so that their engagement in expanding will to increment (Looi et al., 2023).

The over clarification is the impact of the integration of CT in mathematics learning. The impacts displayed appear that CT has a colossal effect on arithmetic learning. There ought to be encourage investigate to see other impacts that emerge which may not have been watched in this

ponder. By looking at the effect of CT integration, it is trusted that analysts will be curious about examining CT-themed inquire about.

#### D. Conclusion

Finally, all the research questions have been answered in this study. It is amazing to see the impact felt by students from the integration of CT in mathematics learning. This CT research revealed that there is a relationship between CT and several students' mathematical abilities such as problem solving ability and improving problem solving skills. Not only can it improve the cognitive side of students, CT can also improve the affective side of students such as increasing creativity, confidence and increasing student involvement in the learning process.

The impact felt is not only in the micro scope (in the classroom), but can also be macro. CT is considered to be able to improve the quality of higher learning so that CT research can be used as a basis in determining a curriculum in a country. There are already many countries that integrate CT as their curriculum such as Australia (Falkner et al., 2014), the United Kingdom (Brown et al., 2014), Finland (Mannila et al., 2014), Sweden (Kilhamn & Bråting, 2019), and the United States (Fisher, 2016).

From this literature review, we conclude that CT can have a broad impact on society, especially in the context of problem solving. Problem solving can be solved with systemic and algorithmic steps as rare in computers. Therefore, the study of CT should still be explored and developed from all aspects, both in its didactic study and the development of software or educational games that can train students to think computationally.

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