INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
OPEN ACCESS JOURNAL
Vol 12, Issue 3, (2023) E-ISSN: 2226-6348

Computational Thinking Activities Among Mathematics Teachers: A Systematic Literature Review

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v12-i3/18988 DOI:10.6007/IJARPED/v12-i3/18988

Published Online: 17 September, 2023

Abstract
In the 21st century, computational thinking is an important skill in many fields, including mathematics education. However, previous studies discussing computational thinking activities among mathematics teachers are still limited. Therefore, a systematic literature review was conducted to examine the trends in previous studies on computational thinking and computational thinking activities among mathematics teachers. Two databases, Scopus and Web of Science (WoS) were used to search for articles published from 2019 to 2023. A total of 633 articles using the keywords "computational thinking" and "mathematics teachers" were found, but only 14 articles met the criteria and were included in this study. This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a systematic approach. Over the past five years, computational thinking activities among mathematics teachers have been studied in eight countries. The research trend is increasing, with most studies involving sample sizes of 1 to 20 teachers. Programming and robotics are the most implemented computational thinking activities among mathematics teachers. Mathematics teachers will benefit from this literature review as it will provide them with a better understanding of computational thinking activities in mathematics education. To enhance mathematics education, further research in this area is hoped to be conducted.
Keywords: Activities, Mathematics, Teachers, Computational Thinking, Systematic Literature Review

Introduction

Computational thinking is a skill that must be mastered in line with the development of 21st Century Education and the Fourth Industrial Revolution (IR 4.0). Therefore, according to Wing (2006), computational thinking is a fundamental skill that everyone needs to acquire as a new literacy for the 21st century. Computational thinking is a problem-solving method that involves the process of formulating problems for computational solutions, organizing and analyzing data logically, using abstractions such as models and simulations, employing algorithmic thinking, assessing efficiency and accuracy, and generalizing and transferring knowledge to other domains (Li et al., 2021).

In general, there are four main concepts in computational thinking, namely pattern recognition, problem decomposition, algorithms, and abstraction (Barr & Stephenson, 2011; Mouza, 2017). Therefore, computational thinking is a method that utilizes the fundamentals of computer science to solve various problems, design systems, and understand human behavior. It can be applied in everyday life. This skill is highly important to apply in teaching and learning, especially in Mathematics, which encompasses various skills, including problem-solving. It cannot be denied that there are challenges for mathematics teachers in implementing computational thinking activities, especially in the teaching and learning of mathematics. Reichert et al (2020) defined computational thinking skills as very difficult to integrate into education, particularly in mathematics education. This is because mathematics education is often perceived as a challenging and tedious subject, posing a challenge for teachers to implement computational thinking activities within the context of mathematics education.

Various studies have been conducted on computational thinking, including evaluations of its implementation Tang et al (2020), as well as investigations into conceptual frameworks and models used in the field of computational thinking (Filzah et al., 2019; Nor, 2020; Tikva & Tambouris, 2021). Additionally, systematic literature reviews have highlighted the implementation and application of computational thinking in classroom contexts (Rogers, 2020), computational thinking in mathematics Li et al (2022), and students' computational thinking in mathematics education (Wan et al., 2023). However, the analysis of previous research reviews indicates that systematic literature reviews specific to this study are limited. Therefore, the purpose of this study is to examine the trends and activities related to computational thinking among mathematics teachers.

The objectives of this study include the following

i. To determine trend of empirical research on computational thinking activities among mathematics teachers in terms of the year of publication, country, and study sample.
ii. To identify computational thinking activities among mathematics teachers.

The research questions are as follows:

i. What is the trend of empirical research on computational thinking activities among mathematics teachers in terms of the year of publication, country, and study sample?
ii. What computational thinking activities are carried out by mathematics teachers?

Methodology

Systematic literature review (SLR) was used to study computational thinking activities among mathematics teachers. A systematic literature review is a systematic and comprehensive research method that can be produced by identifying, evaluating, analyzing and synthesizing past studies that other researchers have conducted (Fink, 2019). This study was conducted with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model which has four phases that need to be gone through in the selection of articles for this systematic literature highlight, namely identification, screening, eligibility, and inclusion. According to Shafril et al (2020), PRISMA and RAMESES can suggest what should be shown in SLR articles in addition to being a guide for a systematic review. In addition, the PRISMA model is used with the aim of completing the reporting that allows the reader to assess the appropriateness of the method and the reliability of the findings (Page et al., 2021).

Through this model, researchers can find relevant articles and fully synthesize them to produce systematic literature highlights organized through the four phases.

Identification Phase

The first step in this identification phase is to determine the source to find articles related to this study. The reference database source is from electronic media sources in the field of education and social science. The Scopus and Web of Science (WoS) websites are the databases used to search for this research article. Their selection is because the articles referred to are articles with a high impact and become a reference source for other studies. According to Zamimah and Noraini (2020), Scopus is the largest multidisciplinary citation index database published by Elsevier, while WoS is a database that has high-quality indexes such as JCR (Journal Citation Report) (Durán-Sánchez et al., 2019). The study is also conducted in a peer review based on articles that have been published in journals. The articles studied have a research focus on computational thinking activities among mathematics teachers. All these articles are also open access articles in the field of education and use English. The publication of the articles used as a source for this study covers the past five years, starting from 2019 to 2023, to see the latest research trends.

Boolean operators and truncation techniques have been employed to facilitate effective article searches related to this study. The following search terms or keywords were utilized in each database search: computational thinking, teachers, and mathematics subjects. Additionally, alternative keywords with similar meanings were utilized to enhance the precision of article retrieval (Shafril et al., 2020). All searches were conducted based on the title and abstract of the studies. Certain search limitations were implemented in accordance with the predetermined selection criteria. The initial search results are presented in Table 1.

Table 1
Initial Search Results

Keywords used	Database	Results
TITLE-ABS-KEY (("Computational thinking" OR "Comput thinking" OR "CT") AND ("Teache*" OR "Tuto*") AND ("Math" OR "Mathemati*" OR "Mathematical"))*	Scopus	371
TS=(("Computational thinking" OR "Comput thinking" OR "CT") AND ("Teache*" OR "Tuto*") AND ("Math" OR "Mathemati*" OR "Mathematical"))*	Web of Science	262

Screening Phase

The screening phase is a process of selecting articles that are relevant and appropriate for the systematic literature review (SLR) based on predetermined criteria. This process is also automated by the database. During the filtering phase, article screening was conducted in accordance with the established criteria. The screening process is illustrated in Figure 1. The inclusion and exclusion criteria that have been defined are presented in Table 2.

Table 2
The Inclusion and exclusion criteria

Criteria	***Inclusion***	***Exclusion***
Literature type	Journal (research articles)	Book, book series and chapters, systematic review articles as well as conference proceeding
Language	English	Non-English
Timeline	Between 2019 and 2023	Before 2016
Index	Scopus and WoS	Besides Scopus and WoS
Country	Around the world	Specific country

The total number of articles after completing the screening process is 18 articles from Scopus and 35 articles from WoS. A comparison between the two databases was conducted, revealing one article that appeared in both databases, indicating overlap.

Eligibility Phase
The eligibility phase represents the third step in the systematic search process and serves as a secondary screening. All articles that successfully passed the initial screening phase underwent qualitative evaluation using a three-tiered approach: low, moderate, and high (Petticrew & Roberts, 2006). This assessment was conducted by two assessors, Assessor A and Assessor B. Prior to evaluation, both assessors engaged in discussions to establish three exemplary articles as benchmarks for each level: low, moderate, and high. Two evaluations took place within this phase: the first involved evaluating the abstracts in relation to the research questions. Following this assessment, 25 articles in total were selected. The second evaluation involved a comprehensive reading of articles that specifically focus on computational thinking activities among mathematics teachers. After this second evaluation, only 14 articles were deemed suitable and utilized as reference sources for the systematic literature review conducted in this study.

Inclusion Phase
A total of 633 articles were initially identified from the two databases. However, all articles underwent screening based on the pre-established criteria before the researcher progressed to the subsequent stage, resulting in the acceptance of only 14 articles for inclusion in this study. Figure 1 below depicts the PRISMA flow diagram.

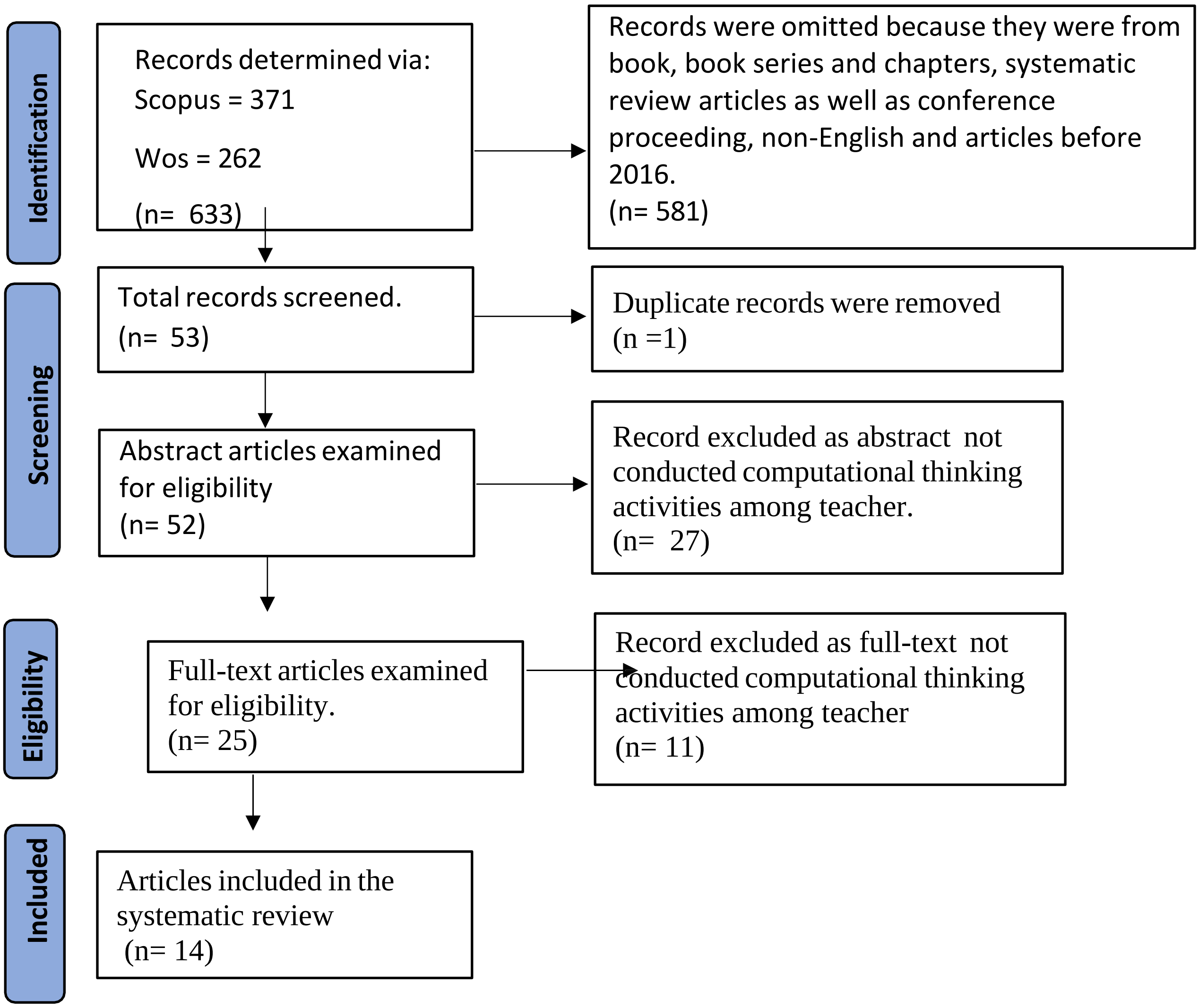

Figure 1: PRISMA Model (Page et al., 2021).

Data Analysis

Thematic analysis (Braun & Clarke, 2006) was employed as the data analysis technique in this study due to the qualitative nature of the data collected. Thematic analysis enables the identification, analysis, and reporting of themes or patterns within the gathered data. Following Braun and Clarke's (2006) framework, the analysis encompassed six phases. For this study, specific themes were predetermined by the researchers to be emphasized during the thorough reading of the articles and subsequent data analysis. The focal theme centered on computational thinking activities among mathematics teachers as presented in each article.

Results

The Trend of Empirical Research on Computational Thinking Activities among Mathematics Teachers in terms of the Year of Publication, Country, and Study Sample.

Year of Publication

Figure 2 displays the publication years ranging from 2019 to 2022, with no publications available for 2023 as it is still ongoing. The research trend on computational thinking among mathematics teachers exhibits a progressive increase from 2019 to 2022. In 2019, there were two publications (Lee & Malyn-Smith, 2019; Otterborn et al., 2019) while in 2020 and 2021, three studies were published in each year (Erdogan, 2020; Kjällander et al., 2021; Piedade et al., 2020; Seckel et al., 2021; Zampieri & Javaroni, 2020; Zieffler et al., 2021). Notably, 2022 witnessed a substantial rise in the number of studies on computational thinking among mathematics teachers, with six publications (Avcı & Deniz; 2022; Knie et al., 2022; Mamolo et al., 2022; Molina-Ayuso et al., 2022; Olsson & Granberg et al., 2022; Umutlu, 2022). As the year 2023 is still ongoing, no publications are reported for this year.

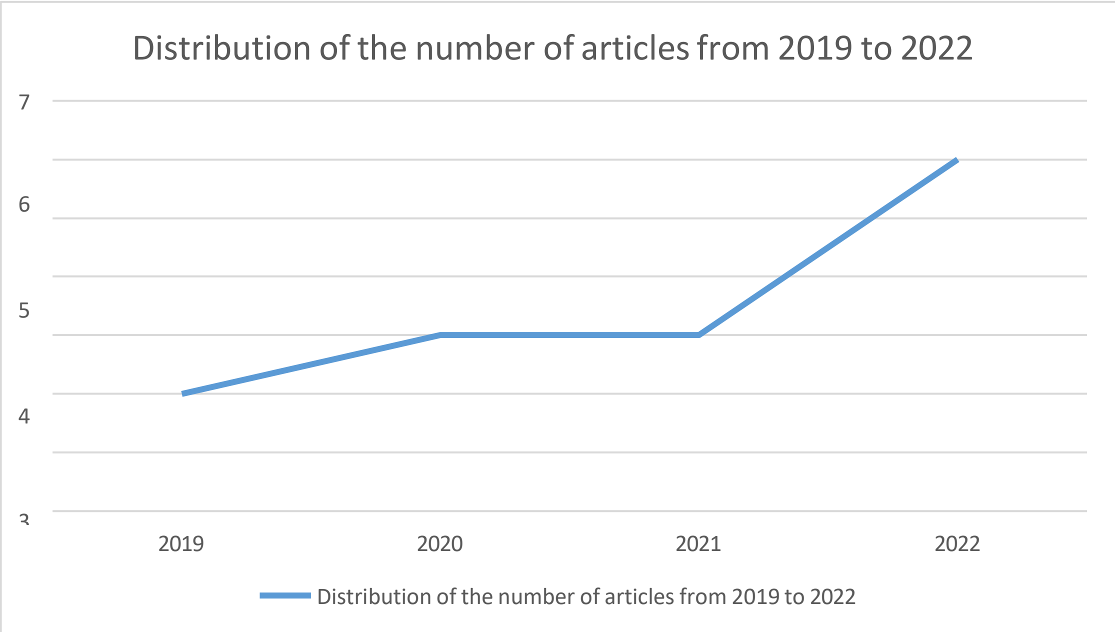

Figure 2: Distribution of the number of articles from 2019 to 2022

Publications by Country

According to Figure 3, a total of eight countries have participated in the study. The country that conducts the most recent studies on computational thinking among Mathematics teachers is the United States of America (Kjällander et al.,2021; Lee & Malyn-Smith, 2019; Seckel et al., 2021; Zieffler et al.,2021) which is four studies followed by Turkey with three studies (Avcı & Deniz, 2022; Erdogan, 2020; Umutlu, 2022), Sweden with two studies (Olsson & Granberg, 2022; Otterborn et al.,2019) while other countries such as Brazil (Zampieri & Javaroni, 2020), Canada (Mamolo et al., 2022), Germany (Knie et al., 2022), Portugal (Piedade et al., 2020) and Spain (Molina-Ayuso et al., 2022) only have one study each.

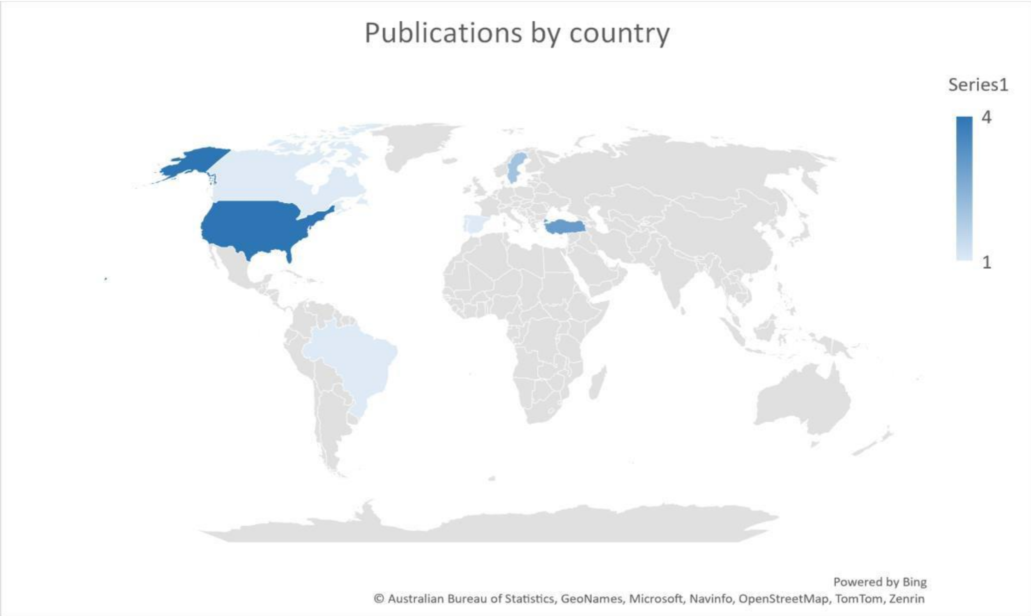

Figure 3: Publications by country

Sample Study

Table 3 below shows the number of sample studies conducted on teachers. There are various numbers of samples used in this study depending on the respective research approach. Therefore, there are various types of sample numbers used to answer research questions.

Table 3

The sample study

Sample Study	Number of articles	Authors
1- 20 respondents	8	Zampieri and Javaroni (2020); Mamolo et al., (2022); Lee and Malyn-Smith (2019); Kjällander et al. (2021); Molina-Ayuso et al. (2022); Olsson and Granberg (2022); Zieffler et al. (2021); Umutlu (2022)
21 - 40 respondents	2	Seckel et al. (2021); Piedade et al., (2020)
More than 100 respondents	4	Avcı and Deniz (2022); Knie et al., (2022); Otterborn et al. (2019); Erdogan (2020)

Computational Thinking Activities among Mathematics Teachers.

Table 4

Computational thinking activities among mathematics teachers

Authors	Theme Computational thinking activities: Programming Activities	Robotics Activities	Learning Framework and Approach	Perception of computational thinking
Avcı and Deniz (2022)				/

Erdoğan (2020)				/
Kjällander et al. (2021)		/		
Knie et al. (2022)			/	
Lee and Malyn-Smith (2019)			/	
Mamolo et al. (2022)	/			
Molina-Ayuso et al. (2022)	/			
Olsson and Granberg (2022)	/			
Otterborn et al. (2019	/			
Piedade et al. (2020)		/		
Seckel et al. (2021)		/		
Umutlu (2022)		/		
Zampieri and Javaroni (2020)	/			
Zieffler et al. (2021)		/		

Programming Activities

Table 4 above shows computational thinking activities among mathematics teachers. As we know, it is impossible to separate computational thinking from programming even when learning mathematics. It's becoming more common for mathematics teachers to use Scratch to improve computational thinking skills. According to Zampieri and Javaroni (2020), there is dialogue and communication during the implementation of Scratch application programming in the teaching and learning of mathematics that can improve computational thinking skills among teachers. Furthermore, teachers who have training and programming expertise in the Scratch application can improve computational skills well (Molina-Ayuso et al., 2022). In addition to the Scratch application, this programming method can also be used on the Makecode application. The use of Makecode in completing climate change kit assignments can improve computational thinking skills (Mamolo et al., 2022). Meanwhile, Otterborn et al. (2019) also support that programming using computers in various applications is one of the methods to increase computational thinking activities among mathematics teachers.

Robotics Activities

Activities related to robotics are also one of the computational thinking activities among mathematics teachers (Kjällander et al., 2021; Piedade et al., 2020). Computational thinking skills such as pattern recognition, algorithms and scaling are aspects emphasized when performing robotics activities. Teachers can also improve these skills by conducting robotics exercises. According to Seckel et al. (2021) teachers also need to know and identify mistakes that occur during robotics activities. This can give teachers the opportunity for self-reflection and can increase computational thinking during teaching and learning.

Learning Framework and Approach

Learning has also been modified to improve computational thinking among mathematics teachers. There is an interdisciplinary integration program framework with computational thinking to help teachers improve computational thinking skills (Lee & Malyn-Smith, 2019). Algorithmic models have also been developed to make it easier for teachers and students to understand statistical subtopics involving computational thinking (Zieffler et al., 2021). This framework and model can provide guidance to teachers to implement computational thinking in a better and more orderly manner. Teachers can also diversify learning strategies and approaches during mathematics teaching and learning sessions. By using a blended learning approach, teachers can foster computational thinking skills while teaching students in the classroom (Knie et al., 2022). According to Umutlu (2022), online learning that is in line with today's technology can also significantly improve computational thinking skills and Technological Pedagogical Content Knowledge (TPACK) among teachers.

Perception of Computational Thinking

Teachers' response to computational thinking also needs to be positive and open to ensure that computational thinking among mathematics teachers can be implemented. Teachers who have a good initial impression of computational thinking can improve confidence enabling them to perform computational thinking better (Avcı & Deniz, 2022; Erdogan, 2020). Various methods of computational thinking activities among mathematics teachers have been carried out, but these methods need to be appropriate to improve computational thinking optimally.

Discussion

Based on this study, there are various past studies showing that computational thinking activities indeed bring a positive impact among mathematics teachers. The development trend of computational thinking can be shown through the analysis of research findings. The study of computational thinking activities among teachers is increasing as the years go by, a trend driven by the attitude of teachers and researchers who realize how important the integration of computational thinking is in learning mathematics. This is because computational thinking can help teachers to teach mathematical concepts more dynamically and relevant to the real world (Humble & Mozelius, 2023). Furthermore, technology and computers have recently experienced rapid development, with mathematics teachers increasingly aware of the potential and use of technology tools in teaching and learning mathematics. This becomes a catalyst for teachers to continue researching the method of computational thinking activities in mathematics education.

Many countries have studied computational thinking in teachers, and this shows that every mathematics teacher should possess it. In general, most countries that are active in conducting research related to computational thinking activities among mathematics teachers emphasize the importance of mathematics education. As such, they have taken the initiative to conduct study to see the effectiveness of the integration of computational thinking in the teaching of mathematics in the country. Computational thinking activities are very effective because they can improve students' understanding of problem-solving skills (Sezer & Namukasa, 2021). However, there are differences in the number published by country, and which are driven by various factors such as the direction of the education system, funding sources and cultural factors.

In terms of the teacher sample, there are many studies involving a qualitative approach where a sample of one to 20 teachers is used in a study. The number of samples used is very suitable for a qualitative approach study. Most studies have used a qualitative approach because they can see the effects more clearly in addition to having strong evidence such as interview recordings, work results and diary entries. Qualitative methods enable in-depth exploration of the experiences and perspectives of students and teachers involved in computational thinking activities (Ramaila et al., 2023). The number of samples in this study is also driven by the number of teachers and the study of computational thinking activities in mathematics is limited. The population of mathematics teachers who have knowledge and experience in computational thinking may be limited in a study area. In this case, the researcher may only be able to collect a limited sample related to this study.

Furthermore, there are various methods of computational thinking activities among mathematics teachers. Mathematics teachers have begun to integrate computational thinking through programming and robotics and several related existing applications can be used to improve computational thinking skills among mathematics teachers. This skill is in line with the current situation which focuses on 21st century skills and IR 4.0. According to Subramaniam et al. (2022) computational thinking activities are not limited to the use of technology alone; there are frameworks, models and approaches that can be used to improve computational thinking among mathematics teachers without using technology. This framework, model and approach can be used as a guide by teachers in improving computational thinking skills. Finally, the most important thing for computational thinking activities is to start from the teacher him or herself. Teachers need to have an initial view and positive thinking toward computational thinking. This can increase their confidence to use computational thinking skills well and perfectly.

Conclusion

Research trends show that computational thinking is becoming more and more emphasized in education, especially in mathematics. In order to form teachers who are up to date with the world, their thinking needs to include computational thinking skills. Teachers can use computational thinking to generate critical and creative thinking. Therefore, computational thinking activity methods need to be appropriate so that their use can have a meaningful effect on teachers carrying out teaching and learning well. Mastery of effective computational thinking methods plays an important role in producing excellent, brilliant and distinguished teachers. This ensures that teaching objectives are achieved. As a result, teacher educators, especially mathematics teachers, should be exposed to computational thinking that combines various domains and can be applied to the classroom. It is hoped that research like this will be extended to research on school students. There is a need for this to help in education, especially in the field of mathematics education in Malaysia.

This research plays an important role in helping mathematics teachers learn more about computational thinking activities in their classes. It gathers information from many studies to give teachers, especially mathematics teachers, a clear picture of what's happening in computational thinking activities. This research doesn't just stay in theory; it also provides practical ideas to teachers. It tells them how to improve their computational thinking by carrying out various activities. In today's world, being good with computers is important for carrying out computational thinking activities. But these activities among teachers can even happen without computers too. They must be suitable for the level and atmosphere in Mathematics class. In simple terms, this research helps mathematics teachers understand and carry out more computational thinking activities to ensure their students are ready computational thinking as a one way to study in mathematics subjects.

Limitations

This study has several limitations, including that the study was based on article papers only. Therefore, the results computational thinking activities cannot be generalized. Future researchers may consider collecting more data and having a more extensive research area. In addition, the study focuses only on mathematics teachers so that future researchers may investigate other subjects (such as science, social studies, art, or others) with similar variables. These computational thinking activities also focused on teacher only and need to make further studies among students too. For example, a study could be conducted to compare the differences between teachers and students in terms of their understanding of computational thinking activities.

Recommendations

This systematic study reveals computational thinking activities among mathematics teachers. These findings have important implications for policymakers and educators. As a result, a more thorough investigation must be performed so as to tackle the obstacles blocking the improvement of computational thinking activities among mathematics teachers. To achieve this, it is necessary to provide appropriate resources and tools that can help teachers develop their computational thinking abilities. Additionally, teachers should be encouraged to actively participate in professional development programs to improve their understanding of the topic. A larger database can also be used to provide further progress in future studies. This study is expected to spark further research to improve these abilities, especially in Malaysia and in the mathematics field. Therefore, it is important to invest in the development of teachers and the resources available about computational thinking, to ensure that students have access to the best education possible.

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