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Mathematical Computational Thinking : Systematic Literature Review

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a b s t r a c t

One of the key math learning goals that students at school must attain is mathematical computational thinking. This research attempts to review research on mathematical computation thinking done between 2018 and 2023. A systematic review of the literature (SLR) was conducted on all papers listed in Google Scholar, Semantic, and ERIC. The PRISMA protocol served as a guide for the research instrument while the search technique was modified to the selection criteria. The year of publication, education level, research class, demographics, journal indexer, and content studied are the variables in this study. The presentation of all data is quantitative descriptive. The findings of the SLR investigation indicate that in 2022 there will be a large publication of papers pertaining to students' mathematical computational thinking. The majority of these studies are conducted in grades VIII and IX in junior high schools. The study of numbers and algebraic concepts was very prevalent in Java and Bali. Future educators and researchers are advised to conduct additional research on computational thinking in mathematics starting at the elementary school level, outside of Java and Bali, on subjects other than algebra and number as well as research-related computational thinking indicators.

K e y w o r d s :
Mathematical Computational Thinking, Systematic Literature Review, PRISMA Protocol, Moderator Variables

INTRODUCTION

Mathematics is one of the important subjects to be learned by students at every level of education. The ability to think mathematically is a capability that needs to be developed in development. Almost all areas of science and mathematics have seen advancements in computing over the past 20 years. Bioinformatics, computational statistics, and neuroinformatics are a few examples. The community of STEM educators as well as organizations dedicated to the teaching of computer science have acknowledged this significant advancement in relation to mathematics, science, and the broader subject of Science, Technology, Engineering, and Mathematics (STEM) (Weintrop et al., 2016).

The ability to think mathematically has an important role in learning mathematics (Christi & Rajiman, 2023; Mania, 2021; M. Taufik Qurohman et al., 2019). However, based on the results of a study conducted by (Gandhi, 2020) it shows that the level of students' computational thinking ability is in the low category with an average of 57.50. The results of another study from the 2015 TIMSS (Trends International Mathematics and Science Study) research were ranked 45th out of 50 participating countries with a score of 397 points. This score is below the 2015 TIMSS average, which is 500 points. On the assessment dimension, the scores of Indonesian students on the number aspect are 24%, the data aspect is 28%, the geometry aspect is 31%, the knowledge aspect is 32%, the application aspect is 24%, and the reasoning aspect is 20%. While the average results of all participating countries on the number aspect are 49%, the data aspect is 57%, the geometry aspect is 50%, the knowledge aspect is 56%, the application aspect is 48%, and the reasoning aspect is 44%. This shows that Indonesia is below average. Based on the results of an analysis related to TIMSS 2015, the ability to integrate information, draw conclusions and generalize knowledge is part of the computational thinking skills that need to be improved in Indonesian students (Hadi, 2021). From the Study (Gandhi, 2020) and TIMSS, it can be concluded that the quality of learning mathematics in Indonesia is still very low. This means that the goals of learning mathematics have not been achieved. Indonesia's low mathematical score is related to mathematical computing abilities.

Seymour Papert coined the phrase "computational thinking" in 1980 and 1996. It is anticipated that the development of computational thinking abilities will help pupils make decisions and solve challenges (Malik et al., 2019). The ability to formulate problems and communicate answers in a way that allows computers, humans, or machines to function successfully is known as computational thinking(Wing, 2017). Students who are proficient in calculation may tackle typical problems that call for such skills with ease. Mathematical computation skills are crucial for pupils to master because of this.

According to (Rijal Kamil et al., 2021) there are several indicators of mathematical computing ability Decomposition, Abstraction, Algorithm, Generalization, and Debugging. The details are as follows:

Table 1
Mathematical Computing Ability Indicator

Ability Indicator	Competency Indicator
Decomposition	Students can identify problems to be simpler so that they are easy to understand.
Abstraction	Learners can decide what information to keep and what to ignore
Algorithm	Students can mention the steps to get the right solution in solving the problem
Generalization	Students can generalize problems into new problems and determine fast and appropriate solutions based on what they have learned.

Debugging	Students can ensure that they choose a fast and appropriate solution, and find errors in the process of solving problems and fixing them.

Meanwhile, according to (Jamna et al., 2022) and (Lestari & Roesdiana, 2023) there are several indicators of mathematical computing ability, including:

Table 2
Mathematical Computing Ability Indicator

Ability Indicator	Competency Indicator
Decomposition	Students can identify problems to be simpler so that they are easy to understand
Pattern recognition	Students can look for similarities or patterns found in the questions
Algorithms	Students are asked to understand and analyze the problem, develop a sequence of steps to get the right solution
Debugging	Students can ensure that they choose a fast and appropriate solution, and find errors in the process of solving problems and fixing them.

Research on mathematical reasoning abilities has been carried out by many previous researchers, for example research (Baist et al., 2019; Jamna et al., 2022; Mania, 2021; Mufidah, 2018; Rijal Kamil et al., 2021), and research other. It is necessary to conduct a thorough analysis of the studies on the use of mathematical computing skills in learning. This is why research on mathematical computing skills is done in the form of an organized review. The systematic literature review (SLR) research methodology is applied. SLR is a research methodology that tries to thoroughly uncover and synthesize research that responds to particular issues utilizing systematic, open-ended, and repeatable techniques at every stage of the process (Ariati & Juandi, 2022c, 2022a, 2022b).

Data collection is in the form of research results related to mathematical computational abilities which are then extracted, with research questions how to describe mathematical computational abilities based on the year of publication, study level, class, demography, journal indexing and how the research results are related to the mathematical computational abilities studied. In this study, the main objective was to describe mathematical computational abilities in terms of the year the article was published, level of study, class or semester, research locations, journal indexers and to summarize research results related to mathematical computational abilities in learning.

METHODS

Systematic Literature Review

This study employed the systematic literature review (SLR) methodology. Using a quantitative, descriptive strategy based on surveys (Litte et al., 2008). The poll was based on secondary data, specifically the outcomes of fundamental investigations into pupils' mathematical computing skills. Data gathering, data analysis, and conclusion-making are among the steps of the research (Juandi & Tamur, 2020). Primary research that has been published in papers for national journals, data from electronic databases registered and indexed by Google Scholar, Semantic Scholar, ERIC, and direct URLs of national journals make up the data that has been gathered. All of the discovered articles were then extracted. The analysis stage only contains articles that are pertinent and satisfy the inclusion criteria (Juandi & Tamur, 2020); (Jesson et al., 2011).

Inclusion Criteria

To obtain data that is in accordance with the research objectives, an inclusion criterion is needed. The following inclusion criteria were used: (1) Evaluation studies in the field of mathematics; (2) This study must analyze mathematical computing abilities (3) The research sample must consist of students from elementary school (SD) to tertiary education (PT); (4) The study must contain classes from the sample education level; (5) studies must contain a large number of samples or participants in the research (6) studies must be conducted throughout Indonesia and have been published in 2018 or later; (7) the study must include the approach or method used. The systematic review study process rejected primary studies that did not match the inclusion criteria during the study selection process.

Research Instruments

The research tool took the shape of observation sheets or procedures with inclusion and exclusion criteria based on the year of publication, level of study, number of samples, research location, journal indexer, and materials utilized. The protocol that the author uses is the PRISMA Protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analysis). Identification, screening, eligibility, and inclusion were the four stages of the PRISMA-based primary study selection procedure (Juandi & Tamur, 2020), (Liberati et al., 2009).

Population and Sample

The population in this study is all research on mathematical computing abilities published in indexed journals. Based on a search using a search engine, a sample of 25 research articles was found that met the inclusion criteria.

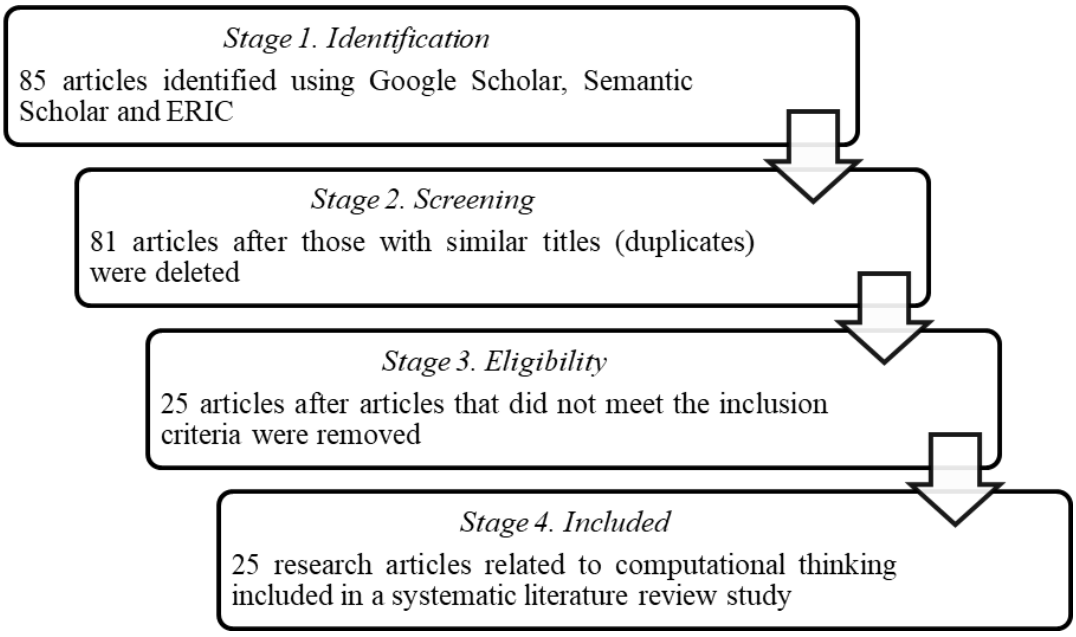

Figure 1
The PRISMA Diagram Studies Mathematical Computational Abilities

RESULT AND DISCUSSION

Criteria-Based Studies

By applying the inclusion criteria to the relevant studies, the articles were further categorized further based on study characteristics or moderator variables, namely publication year, study level, class or semester, research location, journal indexer, and research material. The data is presented in Table 1. There is visible diversity in related studies mathematical computational ability based on study characteristics.

Table 3
Number of Studies Based on Criteria

Studies Characteristic	Criteria	Frequency
Year of Publication	2018	1
	2019	2
	2020	3
	2021	6
	2022	10
	2023	3
Educational level	Elementary School	4
	Junior High School	9
	Senior High School	4
	University	5
	Not Mentioned	3
Research Class	IV	1
	V	1
	VII	1
	VIII	4
	IX	4
	XI	3
	3rd Semester	1
	Not Mentioned	10
Journal Indexer	S3	7
	S4	7
	S5	3
	Google Scholar	8
Research demographics	Jawa & Bali	20
	Sulawesi	1
	Maluku	1
	Kalimantan	1
	Not Mentioned	2
Research Materials	Algebra	5
	Number	5
	Bebras Task	3
	Geometry	4
	Computational Mathematics	2
	Not Mentioned	6

Studies Based on Publication Year

The studies used as data in this systematic review study were published from 2018 to 2023. Details of the distribution of primary studies from 2018 to 2023 are presented in Figure 2.

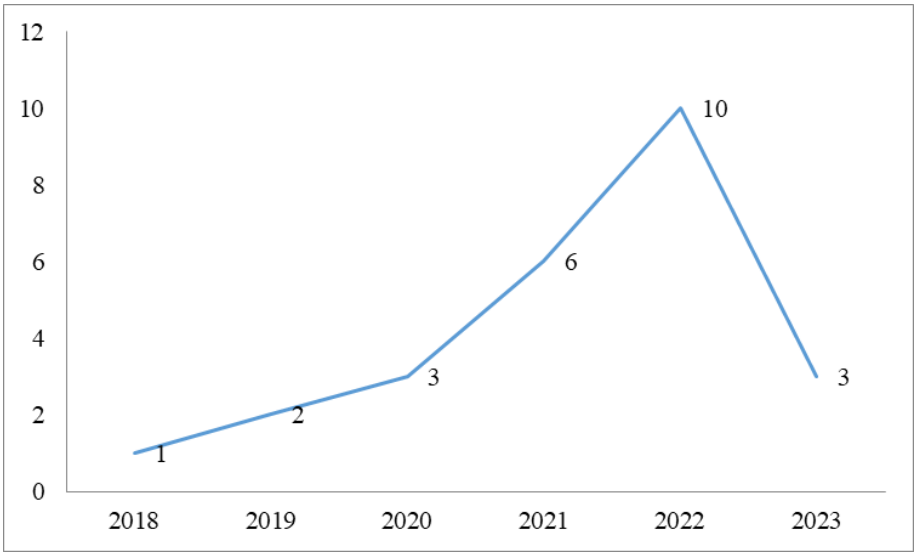

Figure 2
Mathematical computational thinking research data by year of publication

From Figure 2. it can be concluded that the number of studies related to students' mathematical computational abilities published from 2018 to 2023 has relatively increased from year to year. Studies related to students' mathematical computational abilities were published the most in 2022. And still very few were published in 2018.

Studies Based on Educational Level

Studies related to students' mathematical computing abilities which are used as data in the study. This systematic review was carried out from elementary school to university. Details distribution of primary studies from elementary school to tertiary level in Figure 3.

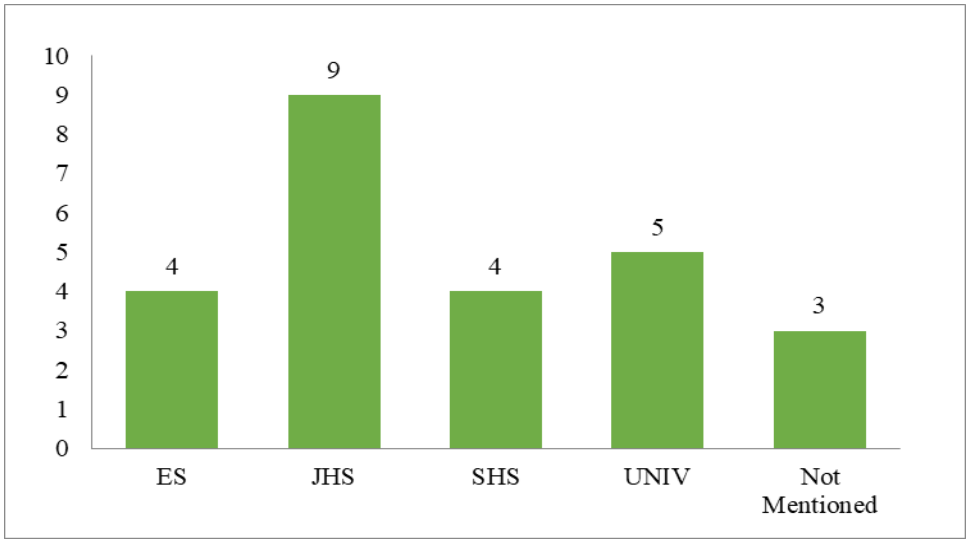

Figure 3
Mathematical computational thinking research data by year of educational level

From Figure 3 it can be interpreted that mathematical computational abilities are more researched and studied at the junior high school level, whereas in elementary schools there is still little research related to mathematical computation that is conducted and published. This is a concern because mathematical computing ability is a very important competency to be developed from an early age. This is supported by research (D. Juandi, 2021) which says that all mathematical abilities, especially problem solving skills, are studied more at the junior high school level compared to other mathematical abilities.

Study Based Research Class

The studies used as data in this systematic review study were published from 2018 to 2023. Details of the distribution of primary studies from 2018 to 2023 are presented in Figure 2.

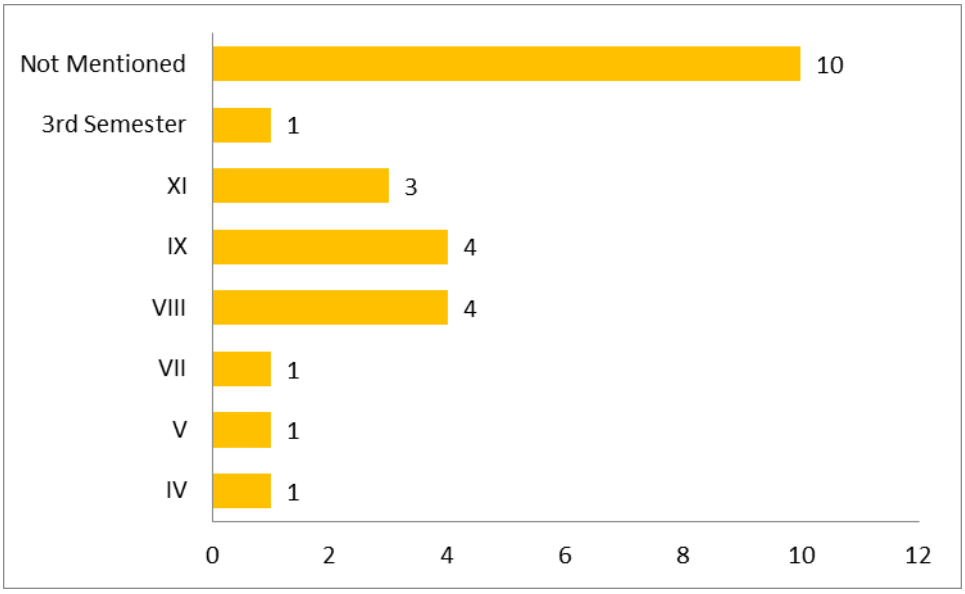

Figure 4
Mathematical computational thinking research data by research class

Research related to students' mathematical computing abilities which are used as data in this systematic review study can be carried out from grade IV in elementary schools to tertiary institutions. Details of the distribution of primary studies from grade IV elementary school to tertiary institutions are shown in Figure 4. It can be seen that mathematical computing abilities are more researched and studied in grades VIII and IX, while in elementary schools there is still little research related to mathematical computation that is carried out and published, namely only in class IV as much as one study and in class V as much as one study. Also for high-level classes, for example from class XI to college level, studies related to mathematical computing abilities have decreased.

Study Based Research Demographics

Details of the distribution of studies based on demographics related to mathematical computing ability from Sumatra to Papua are presented in Figure 5.

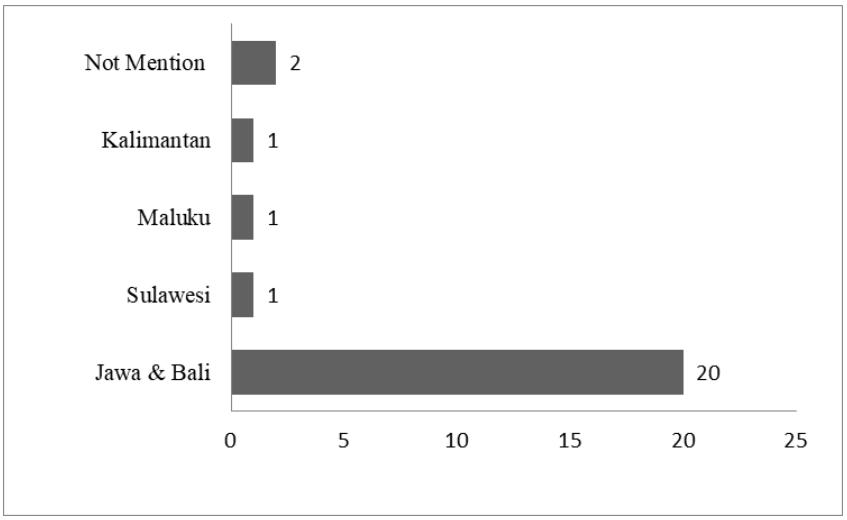

Figure 5
Mathematical computational thinking research data by research demographics

Based on Figure 5. It can be concluded that research related to students' mathematical computing abilities is dominated by the Java & Bali regions, while for other regions it is still small. From review studies obtained in the regions of Kalimantan, Maluku and Sulawesi, research related to computational capabilities is still small, namely one study each.

Study Based Journal Indexed

Details of the distribution of studies based on demographics related to mathematical computing ability from Sumatra to Papua are presented in Figure 5.

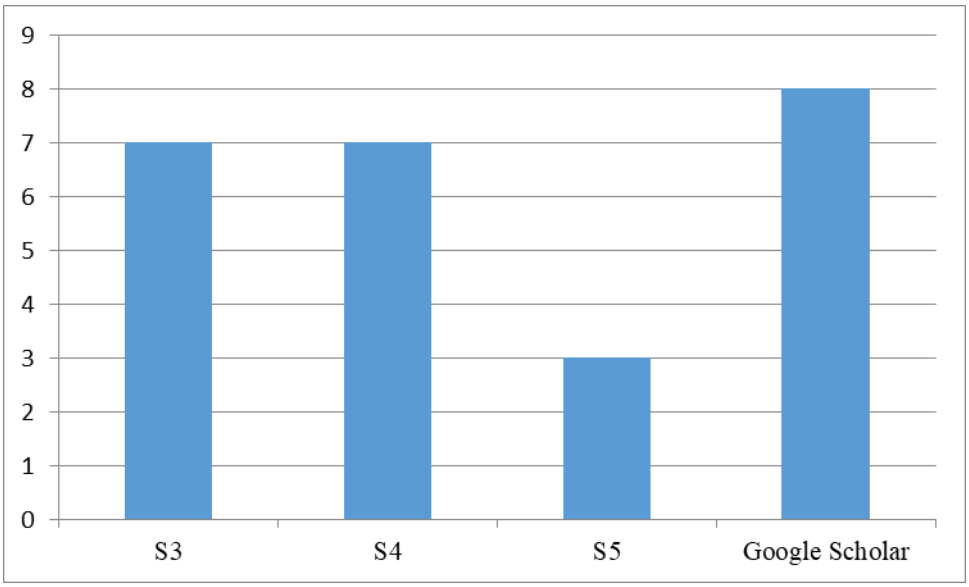

Figure 6
Mathematical computational thinking research data by journal indexed

Details of the distribution of studies based on journal indexers related to mathematical computational abilities are presented in Figure 6. It can be concluded that the results of studies related to students' mathematical computational abilities are mostly published in Google Scholar indexed journals, then Sinta 3 & 4. As for indexed journals Sinta 5 is still a little.

Study Based Research Material

Details of the distribution of studies based on research materials related to computational thinking presented in Figure 7.

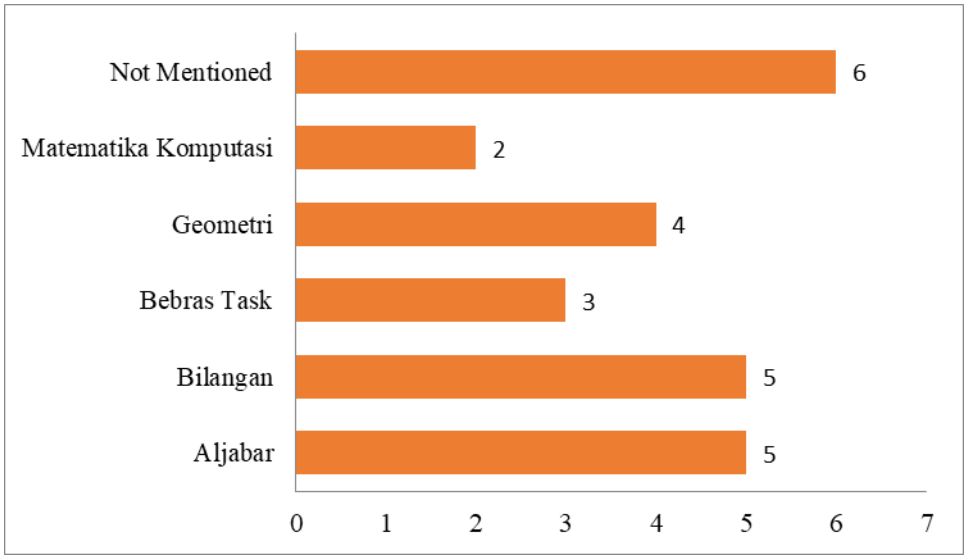

Figure 7
Mathematical computational thinking research data by research material

From Figure 7, it can be concluded that the results of the study related to the mathematical computing abilities of the majority of students tested related to algebraic material and numbers. As for material on computational mathematics, little has been done.

Based on the teaching materials used, there is an increase in the mathematical computational thinking abilities of students who receive learning using interactive multimedia-based teaching materials (Angraini et al., 2022). Then the developed computational thinking skills instrument contains 4 aspects of computational thinking skills, namely 1) problem decomposition, 2) algorithmic thinking, 3) pattern recognition, and 4) abstraction and generalization (Jamna et al., 2022; Maksum, 2022; Mufidah, 2018; Putri et al., 2022; Rara et al., 2022). Several learning models or approaches that can be used to improve mathematical computing abilities include PBL learning with the help of Edmodo (Marifah & Kartono, 2023), Mathematica software-assisted learning (Baist et al., 2019), learning with the help of mathlab software (M T Qurohman et al., 2022), learning with multimedia (Angraini et al., 2022), and learning with a question-based approach based on Islamic culture (Nurmuslimah, 2019).

CONCLUSION AND IMPLICATION

Conclusion

Research on mathematical computing abilities has received good attention, especially in the last few years, 2022. The majority of these studies were conducted at the junior high school level in grades VIII and IX. Studies are also dominated in the Java & Bali regions in geometry and algebra material. Suggestions for educators or researchers to be able to further research mathematical reasoning abilities from the elementary school level, in areas outside Java & Bali, on materials other than algebra and numbers. Researchers are advised to be able to do more research related to aspects of indicators in mathematical computing because they are still very minimally researched.

Implication

The implication of the results of this study is that in conducting research related to mathematical computation it can be directed to enrich knowledge and provide an overview of research that has been carried out. For example related to publication year, study level, class or semester, research location, journal indexer, research material. This study includes several lessons related to efforts to improve mathematical computing abilities. Future educators or researchers to do more research on mathematical computational thinking from the elementary school level, in areas outside Java & Bali, on materials other than algebra and geometry as well as research related indicator of computational thinking.

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