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APPLICATION OF CAME TO IMPROVE MATHEMATICAL THINKING ABILITY AND LEARNING MOTIVATION: A SYSTEMATIC LITERATURE REVIEW

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Abstract

This study aims to identify, evaluate, and draw conclusions from each of these studies on Computer Assisted Mathematics Education (CAME) to provide advice to researchers and practitioners of mathematics education. The systematic literature review (SLR) method was used in this study. Data was collected by selecting several studies based on inclusion criteria and obtaining 54 qualified articles from 2012 to 2023. The result is that the overall implementation of learning with CAME positively affects students' mathematical thinking abilities, especially for high school students. In addition, supporting software is software used to see the effectiveness of applying CAME to mathematical thinking skills with supporting software, namely GeoGebra. The implications and limitations of the research have been discussed and provide recommendations as the basic ideas for future CAME Systematic Literature Reviews

Keywords: CAME, Geogebra, Mathematical thinking ability.

1. Introduction

Computer-Assisted Mathematics Education (CAME)" is the practice of teaching mathematics utilizing computer-dependent cognitive aids [1]. The use of CAME will make math instruction more engaging, creative, and exploratory [2]. The two most important parts of mathematics software are the Computer Algebra System (CAS) and the Dynamic Geometry Software [3]. The definition of CAS is the explanation that software is used to manipulate formulas to solve challenging and tedious mathematical problems [4].

Some of the software included in CAS are Axiom, Macsyma, Maple, Matematica, and Matlab. Software classified as DGS: Cabri Geometry, and Sketchpad [5]. Software that connects dynamic geometry features and algebraic systems on a computer is Geogebra [6]. The ability to think is the most essential component of a person's cognitive processes. Some of the abilities included in the ability to think mathematically are critical thinking skills, creativity, communication, representation, reasoning, spatial, and mathematical understanding [7]. In addition to cognitive abilities, students must also have affective skills. Of the many affective abilities, it is necessary to instil learning motivation in students [8]. The term "motivation" comes from the word "motive," which is the inner energy that drives a person to engage in certain behaviors and achieve specific goals [9]. Motivation is divided into two parts. The first is external motivation through gifts, praise, and grades, including family, teachers, and the environment [10]. The second is internal motivation, according to the characteristics of each student [11].

Systematic Literature Review (SLR) is a research technique that uses precise, structured, and repeatable methods at each stage to find and synthesize research as a whole. Several studies have carried out SLR research [12-14]. Meanwhile, to improve students' higher-order thinking skills, this research does not explicitly discuss SLR, which is associated with applying CAME in learning mathematics This study aims to identify, evaluate, and draw conclusions from each of these studies on Computer Assisted Mathematics Education (CAME) to provide advice to researchers and practitioners of mathematics education. The research method used an SLR (Systematic Literature Review). The novelties of this study are to examine the effect of CAME on mathematical thinking ability and the variability of the impact of the study on CAME on these skills by type of CAME, year of publication, and supporting software.

2. Method

SLR is a method for grouping and combining results that meet specific criteria to address particular problems [15]. The data obtained comes from primary research that has been published as national journal articles and from electronic databases that have been registered and indexed by Google Scholar, Semantic Scholar, Garuda Portal, DOAJ, ERIC, and national journal direct URLs. In addition, all found articles were extracted. At the analysis stage, only relevant articles that met the inclusion criteria were considered. To obtain data that is relevant to the research objectives, the following inclusion criteria were determined: (1) Articles are learning products about teaching mathematics; (2) Articles published between 2012 and 2023; (3) Experiment-based research to improve mathematical thinking skills using CAME: (4) Studies without a control group were excluded from the analysis.

The online search resulted in a selection of 54 experimental studies that were relevant and worthy of systematic evaluation.

3. Results

All relevant studies were classified using inclusion criteria based on four moderating variables: year of study, level of education, type of CAME, and software support. Table 1 displays descriptive data.

Table 1. Description Data CAME.

Criteria	Category	Mathematical Thinking Ability								Learning Motivation	Unknown
		KBKM	KBKsM	KKmM	KRM	KPM	KSM	KPhM	KBTTM		
J CAME	CAS	0	3	5	1	2	0	2	0	2	0
	DGS	1	0	5	0	1	4	0	0	0	0
	CAS and DGS	6	0	5	1	4	2	0	5	1	0
TP	2012-2014	0	0	3	1	2	0	1	2	0	0
	2015-2017	1	1	4	0	0	4	0	0	2	0
	2018-2020	1	1	8	1	4	2	0	3	2	0
	2021-2023	1	4	1	0	1	0	0	0	0	2
SP	Geogebra	7	0	5	1	4	2	0	5	2	0
	Maple	0	0	0	0	0	0	0	0	0	1
	Autograph	0	3	5	1	2	0	2	0	2	0
	Matlab	0	0	1	0	0	0	0	0	0	0
	Cabri 3D	0	0	4	1	0	4	0	0	0	0
JP	SMP	1	2	5	2	0	4	0	3	3	0
	SMA	6	1	11	1	6	2	2	2	1	2

Based on Table 1, over eight years it has been dominated by research on improving mathematical communication skills, effectively published in several indexed journals. This shows that many researchers have reacted to the orientation of learning mathematics outlined in the 2013 curriculum and driven by NCTM. Similarly, research to improve mathematical creative thinking skills is extensive, but research to promote critical thinking skills and mathematical connections is still limited. This is a challenge for researchers to continue to improve mathematical connection skills with the help of CAME. To obtain more specific information, it will then be addressed by the moderator variable that has been set. Because learning that is applied with CAME can bring together students' minds in solving problems with various predictions designed by the teacher and their solutions, learning with CAME can develop students' mathematical thinking abilities. The first criterion is the type of CAME. The grouping is divided into three groups, namely CAS learning, DGS learning, and learning with the help of both (CAS and DGS). Figure 1 illustrates the study based on the three types. CAME.

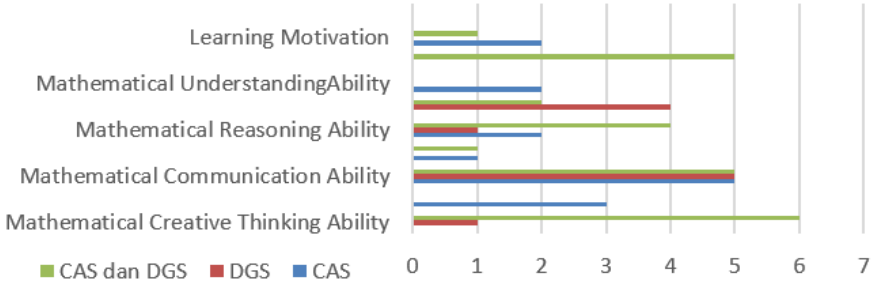

Fig. 1. Data based on came type.

In Fig. 1, all studies were carried out equivalent to the CAME type grouping. CAME research to improve mathematical creative thinking skills is dominated by learning with CAS and DGS. Effect of CAME on improving mathematical communication skills with CAS dominates compared to mathematical spatial abilities in learning with DGS. The research period is separated into 3 periods: 2012-2014, 2015-2017, 2018-2020, and 2021-2023. Study information is presented in Fig. 2.

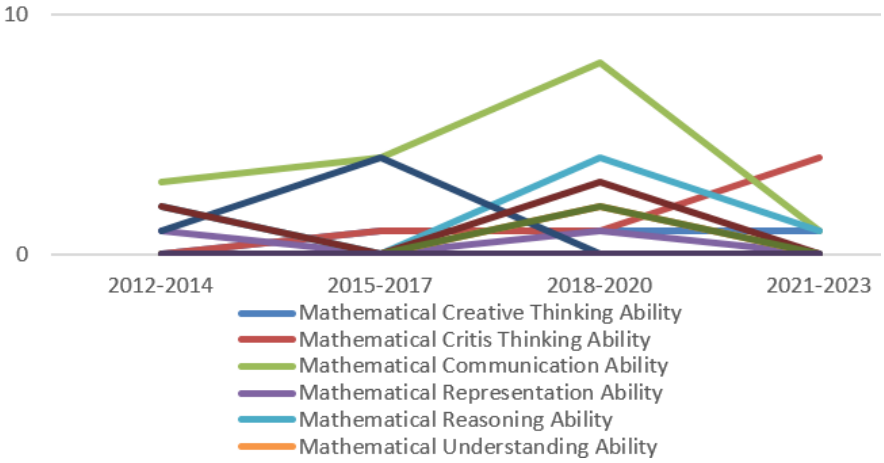

Fig. 2. Data based on research year.

According to the year of publication regarding CAME and the ability to think mathematically in the last eight, as shown in Fig. 2, most articles were published in 2018 - 2020, with 22 pieces each. Meanwhile, in 2021-2023 only nine works were published. It summarizes the data for the year the article was published, which shows that research interest in the CAME issue as a learning model for improving mathematical thinking skills in the form of creative thinking skills, critical thinking, communication, reasoning, understanding, spatial, higher-level mathematical thinking, and learning motivation has experienced increasing and decreasing every year. Based on the supporting software used in CAME, it is divided into five categories, namely Geogebra, Maple, autograph, Matlab, and Cabri 3D. The data display is presented in Fig. 3. CAME research to improve communication skills and creative mathematical thinking for 2012-2023 is the best research with supporting software, Geogebra. Meanwhile, the ability to think mathematically in

the form of thinking creatively, critically thinking, communicating, reasoning, understanding, spatial, higher level mathematical thinking, and research learning motivation with supporting software, namely Cabri 3D. There are two types of educational levels selected in this study, namely: junior high school and high school.

Figure 4 illustrates the number of experimental investigations depending on an academic level. all mathematical abilities, especially creative thinking skills, and mathematical communication, are studied more at the high school level, except for mathematical literacy, usually looked at in high school. There are no published studies of reasoning ability and mathematical understanding in junior high school. This is quite concerning because connecting concepts between mathematics in various problems is a skill that must be possessed in higher education.

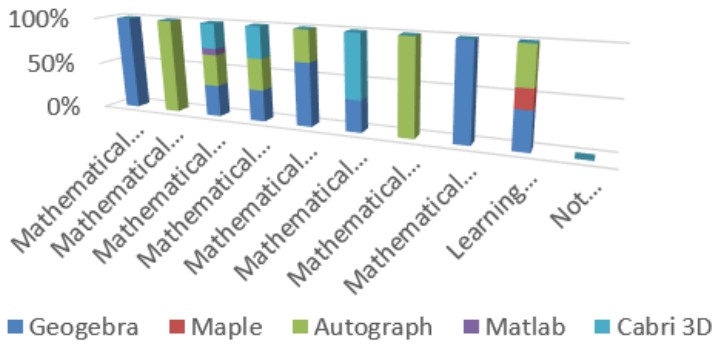

Fig. 3. Data based on supporting software.

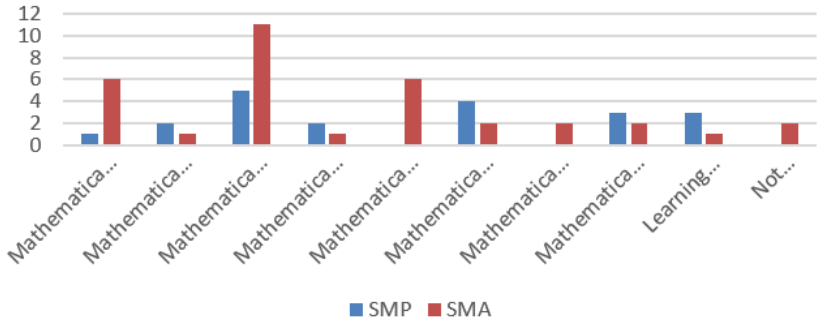

Fig. 4. Data based on education level. SMP is the junior high school. SMA is the senior high school.

4. Discussion

Nevertheless, CAS and DGS are no less important in learning mathematics. Because learning mathematics with CAS, besides being able to improve the ability to think mathematically, can also develop operational and intellectual abilities [16]. Another role of CAS in learning mathematics can make it easier for students to form their representations for students [17]. Meanwhile, DGS in learning

mathematics can help students understand the concept of geometric material, which tends to be abstract [18].

The results of these findings are similar to research conducted [19, 20]. CAME research impacted the ability to think mathematically more frequently between 2009-2018. Mathematical communication ability is the ability that has been researched the most compared to the other three abilities. This suggests that academics are more interested in mathematical communication skills than in investigating critical thinking skills and mathematical connections. An alternative methodology can be used to conduct a broader study of the four mathematical abilities.

This study's findings align with the research findings. Geogebra has a vital role in learning mathematics [21]. Geogebra also has a positive impact on improving students' mathematical thinking skills [22]. As is the case with research conducted that learning mathematics with the help of Geogebra can improve learning outcomes [23]. This is supported by an interactive menu of applets that will produce procedural and conceptual skills. Thus, it can be recommended at all levels of education in Indonesia. In contrast, not much CAME learning has been carried out at the university level, especially about mathematical abilities.

The university level has fewer issues than other educational levels regarding the impact of CAME on students' mathematical abilities [24]. This study informs the need of strategies for teaching mathematics [25-30]. This study gives additional data for the use of literature review in giving research trend, as discussed in other reports [31-38].

5. Conclusion

In this study, 54 articles were identified and classified regarding the role of CAME on mathematical thinking skills based on several criteria, including the educational level of the subjects in the research, supporting software, year of publication, and analysing the effectiveness of the implementation of the PBL model on students' mathematical thinking abilities. In general, it is widely applied at the high school education level with GeoGebra-supporting software. Then, the year of publication that often publishes articles about the role of CAME is 2018-2020. And overall, CAME has a positive impact on students' mathematical thinking abilities compared to direct learning. We suggest, for further research, paying attention to other factors in determining inclusion criteria so that the analysis can be more in-depth.

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