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Computer-based mathematics learning studies in the scopus database between 2010-2023: A blibliometric review

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Abstract

Computer-based Mathematics Learning (CBML) has become global in the last decade, providing opportunities for more significant interaction between schools and their environment. Although CBML has been widely applied, few studies highlight its growth trajectory, especially high-quality studies and those in the Scopus document. This study identifies CBML-related research that can provide a global perspective on learning and the development of the further investigation. Therefore, a bibliometric analysis was conducted to identify 651 journal articles between 2010 and 2023 using the Scopus database. Data search uses the publish or perish application, and the VOS viewer program assists in analyzing theme linkages. This research addresses two issues: (i) reviewing the growth trajectory of CBML-related studies; and (ii) mapping between themes to identify gaps and the most important topics. The analysis results show that the study's trajectory appears fluid and is mediated by the impact of social restrictions due to Covid-19. The main topics and research gaps are discussed. Several implications are presented as helpful information for scientists and stakeholders.

Keywords: bibliometric analysis; Computer-Based Mathematics Learning, scopus

Introduction

Computer-based Mathematics Learning (CBML) has been implemented globally throughout the world. The use of CBML in the classroom is associated with students' academic abilities because teachers provide broader content learning opportunities (McLaren, 2017; Xin et al, 2020; Sarría Martínez de Mendivil et al, 2019; Zhang & Wang, 2020). Applying CBML has a

major influence on improving students' mathematical abilities (Pereira et al, 2021; Nurjanah et al, 2020; Tamur, 2021; Kim, 2022; Kim et al, 2022; Shyshkina, 2017). It can be said that the use of CBML has become a trend in learning mathematics in the last decade.

The use of CBML in learning is increasingly widespread because it presents content numerically, graphically, and symbolically without the additional time burden of manually calculating complex computational problems (Juandi et al, 2021; Tamur et al, 2021). Integrating computer technology into learning mathematics will help students make connections in mathematics by making the learning process more realistic and effective (Tamur, 2021; Colado et al, 2017). CBML implementation will be more interesting, inventive, and exploratory (Foster et al, 2016; Ochkov & Bogomolova, 2015; Tamur, Weinhandl, et al, 2022; Tamur et al, 2023). These conditions allow students to be more active and successful in learning (Das et al, 2021; Tatar et al, 2014; Timmers et al, 2013).

The theoretical assumptions regarding the advantages of CBML have provided a flurry of studies to date to test its consistency. Many studies review the advantages of CBML by conducting meta-analyses (e.g, Chauhan, 2017; Cheung & Slavin, 2013; Demir & Başol, 2014; Juandi et al, 2021; Juandi, Tamur, et al, 2022; Nagendrababu et al, 2019; Sosa et al, 2011; Tamur, 2021; Tamur et al, 2020; Yesilyurt et al, 2019). All of these studies provide quite similar results that the application of CBML positively impacts student academic performance. A recent meta-analysis from Tamur et al (2021) even answered questions that primary studies could not raise regarding the saturation point of CBML use. It was reported that although CBML has advantages, its effect will decrease even if given a long time. Unfortunately, the scientific literature has not extensively explored the trajectory of the study's growth nor an overview of frequently and rarely researched themes.

In fact, in the current literature, the growth and trajectory of studies in general regarding the application of ICT in mathematics learning have been reported by several researchers (e.g, Supinah & Soebagyo, 2022; Tamur, Jedia, et al, 2022; Tamur, Men et al, 2022). However, in this study, the data in the form of research results documents were analyzed and identified from the Google Scholar database. In contrast, this study analyzes research related to applying CBML from the Scopus database. This is because Scopus applies consistent standards in selecting documents for inclusion in its index (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020). Thus, this study aims to fill this gap by attempting to document and synthesize previous research patterns regarding the application of CBML from the Scopus database. In particular, the following two research questions will be examined. First, what is the growth trajectory of studies regarding the application of CBML in mathematics learning? Then the second question is how to map the study and what essential topics there are already a lot and also not yet explored a lot.

Methods

The purpose of this study is to identify global research related to the implementation of CBML to clarify the trend of its use in the future. This goal is achieved by bibliometrics as an analytical

tool. Bibliometric analysis is a popular and rigorous method for exploring and analyzing large amounts of scientific data (Donthu et al, 2021). This method is very objective in revealing trends that appear in large articles and journals (Liu, 2020). Bibliometric analysis techniques are divided into two categories, namely performance analysis and mapping.

Until now, bibliometric analysis has been used in different research topics including those related to mathematics. For example, Özkaya (2018) uses 9,941 documents indexed in the Web of Science between 1980 – 2018 to develop a general layout of knowledge structures and scientific communication in mathematics education. These studies adopted various techniques of bibliometric analysis (ie, statistical description, co-author analysis, mapping of the sciences) to identify the knowledge base of the topics they studied. In addition, Phan et al (2021) analyzed 282 Scopus indexed documents spanning 1972 to 2020 for RME research trends around the world.

In line with this research, this study analyzed 607 Scopus indexed documents between 2010 – 2023 which specifically examined the application of CBML. This work focuses on exploring two research questions as previously described. Relational comagnetic analysis allows readers to explore the structure of ethnomathematics topics, identify topics of most interest in research, and also reveal research trends in these topics (Zupic & Čater, 2015). In the bibliometric analysis, co-occurrence keyword recordings indicated the most common keywords appearing in the documents analyzed by Phan et al (2021) to conclude that certain documents have the same topic and are related if they share some of the keywords specified in the keywords section.

In this study, the Scopus database was chosen as a place to search for documents because Scopus applies consistent standards in selecting documents to be included in its index. In addition, Scopus displays more documents than other top databases such as Web of Science, especially specifically for research reviews in the fields of education and social sciences (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020). Furthermore, the Publish or Perish program is used to capture studies on the application of CBML. The CBML categories for the geogebra, Cabri, maple, algebrator, and wingeom programs (Juandi et al, 2021; Tamur, Kusumah et al, 2021; Tamur et al, 2020). Then, until 2021, there will be two programs resulting from the development of Cabri, namely Cabri Express, New Cabri (Tamur et al, 2022). Figure 1 shows one of the Scopus databases browsing processes using the PoP application.

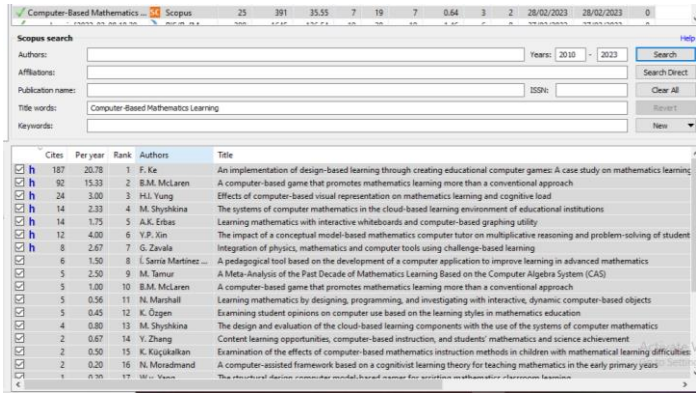

Figure 1. An example of the research tracing process from the scopus database

Figure 1 is the initial procedure for collecting the Scopus database via PoP before the screening. Furthermore, to filter the data collected through PoP, this study follows the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines (see Figure 2).

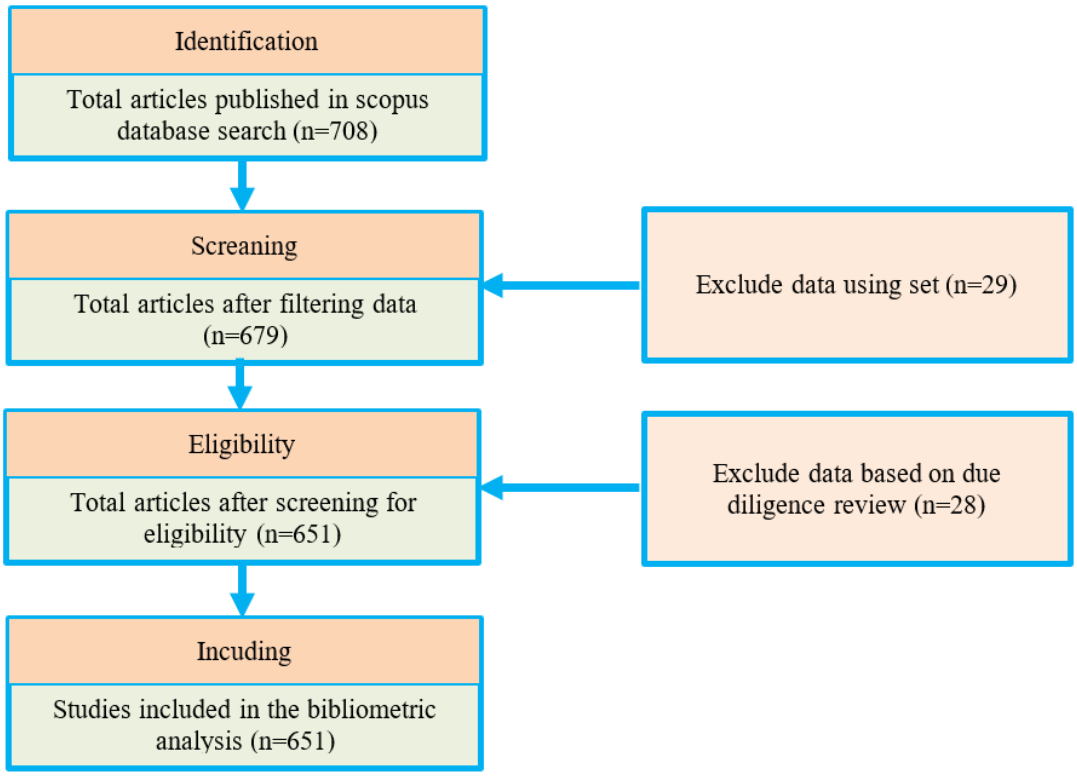

Figure 2. Filtering data through PRISMA

In the identification step, a search is performed using keywords consisting of CBML types. Based on the results of searching data through PoP, 708 articles were obtained which were the population of the study. The results of encoding the variable data extraction results that are exported directly from POP are at the link http://bit.ly/3SwSDjD. The next work is to filter the data based on the stated inclusion criteria, namely (i) Document type: unlimited; (ii) Language: English; (iii) Subject areas: scopus; and (iv) Year of publication: between 2010-2022. In this step, 29 documents were omitted due to duplication. This kind of thing often happens in review research because the databases used are different, but it is possible that the same articles exist in the various databases (Juandi, Suparman, et al, 2022; Juandi, Tamur, et al, 2022; Wijaya et al, 2022) The total documents screened using the inclusion criteria were 679. Then at the feasibility stage the team investigated each document by reading the title and abstract. Each member is given the task of reading and making recommendations for keeping or removing documents. At the end of this step, all members discuss the reasons for omitting certain documents from the data analysis. The research group re-examined the title, abstract, and sometimes the full text of the article to determine whether or not the article should be rejected. In this step, 28 documents were omitted because their contents were irrelevant to the implementation of CBML. So, the final documents that deserve to be included in the bibliometric analysis are 651 studies which are all kept in the RIS file. The application that

helps with the analysis is the VOSviewer software. This application is used for mapping in search of trends in international scientific publications with the Scopus database regarding the application of CBML to learning mathematics according to keywords.

Results and Discussion

This study aims to analyze the four problems proposed. Based on the analysis of the results using the VOSviewer program. First, we present the results regarding the initial research question, namely, what is the trajectory of the study of applying CBML in mathematics learning? In particular, our four-step PRISMA search and identification process resulted in 651 documents related to CBML implementation that deserve analysis. There are two categories of analysis, namely performance analysis in the form of the number of publications each year, articles with the most citations, journals with the most articles, ranking of journals and countries with the greatest number of articles; and scientific mapping in the form of Circles Network Visualization, Frames Overlay Visualization, and Density Visualization. Regarding the timeline, Figure 2 presents the number of documents related to the implementation of CBML in Scopus documents issued between 2010 and 2023.

Figure 3. Number of studies related to CBML 2010 and 2023 (N=651)

Based on Figure 3, it appears that the publication of studies related to the implementation of CBML over a period of thirteen years has fluctuated. Three Figure 3 shows that it is clear that the number of studies in the period 2010 to 2013 has increased slightly. In 2014 research productivity, as reflected in the number of documents in Scopus, decreased quite sharply. This condition can be explained by a mediator variable called the Hawthorne effect (Juandi & Tamur, 2021; Tamur et al, 2021). The Hawthorne effect occurs when students are enthusiastic about learning because of the novelty of the treatment, but when it is given over a long period of time, the effect is less and less. These results have an impact on the need for variations in media use and the importance of implementing games (Tamur, Gahung et al, 2022; Wang & Tahir, 2020).

Furthermore, from the illustration that appears in Figure 3, it is clear that there is a clear increase in the growth trajectory of CBML-related studies between 2014 and its peak in 2020. This result differs from the previous bibliometric analysis's tendency that the largest number of documents existed in 2019 (e.g, Pham-Duc et al, 2021; Tamur, Men et al, 2022). Nonetheless,

the results of this research can be understood, and scientifically it can be explained that documents published in 2020 could have been the result of research in the previous year. In general, the illustration of the trend of CBML implementation studies between 2010 and 2020, as shown in Figure 3, resembles the graph in the study of Phan et al (2021) which explains that the accumulation of publications per year forms an exponential growth curve in the period 1972 to 2019. Other studies also support this finding (e.g, Supinah & Soebagyo, 2022; Tamur, Jedia, et al, 2022; Tamur, Men, et al, 2022) who reported that a list of studies on ICT trends formed an exponential curve. It is clear that there is a tendency to apply CBML in learning that is widely applicable.

2020 became the peak as well as the starting point for the decline of documents on Scopus. The results of this study also show the trajectory of the study, which has decreased from 2021 to 2023 as illustrated in Figure 3. This is possible because in that span of years there has been an outbreak of Covid-19 that has swept the world (Negara et al, 2020; Schleicher, 2020). Most governments have decided to temporarily close educational institutions in an effort to reduce the spread of COVID-19 (Juandi, Tamur, et al, 2022). The education sector has been impacted by the COVID-19 crisis at all levels, from preschool to university and has also resulted in the cancellation of various academic conferences (Ali et al, 2021). This resulted in a lack of mobilization of researchers, including in the field of CBML implementation.

The second objective of this research is to answer questions related to thematic mapping and thematic gaps from emerging studies regarding the use of CBML. From the analysis, results obtained results of Circle Network Visualization Analysis (see Figure 4), Frames Overlay Visualization (Figure 5), and also density visualization analysis (Figure 6).

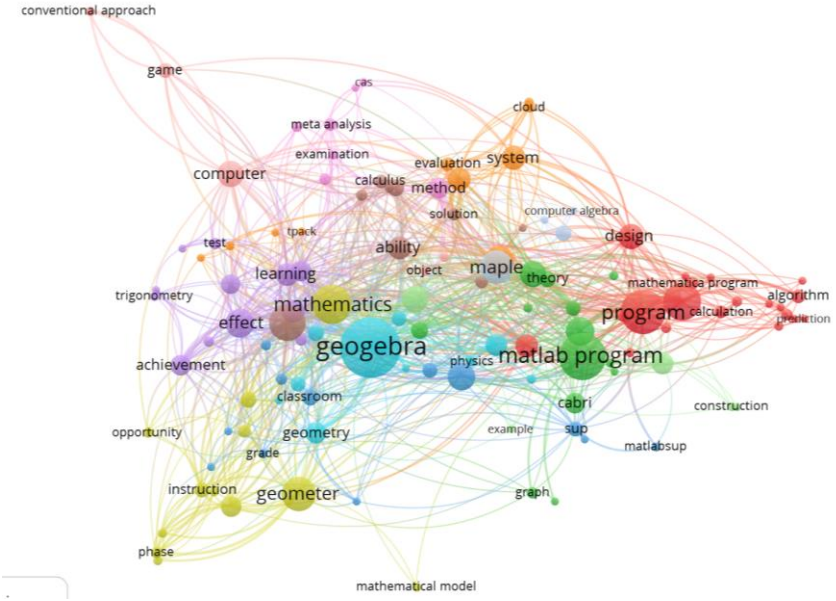

Figure 4. Results of network visualization analysis using CBML

Based on Figure 4, it can be seen that the topic of using CBML is quite varied. This is seen in the 12 colors that represent the twelve theme clusters. From the size of the circle of research themes, it is clear that there are more studies related to the use of GeoGebra and Matlab applications than other types. The Geogebra theme is directly related to themes including

trigonometry, review, mathematical models, lesson study, and geometry. While the matlab theme is related to mathematical models, problems, analysis, and modeling. Figure 5 below illustrates the Frames Overlay Visualization Study on the Use of Geogebra against KPMM to get a clear picture regarding the trend of the theme of writing articles in journals taken from the Google Scholars database.

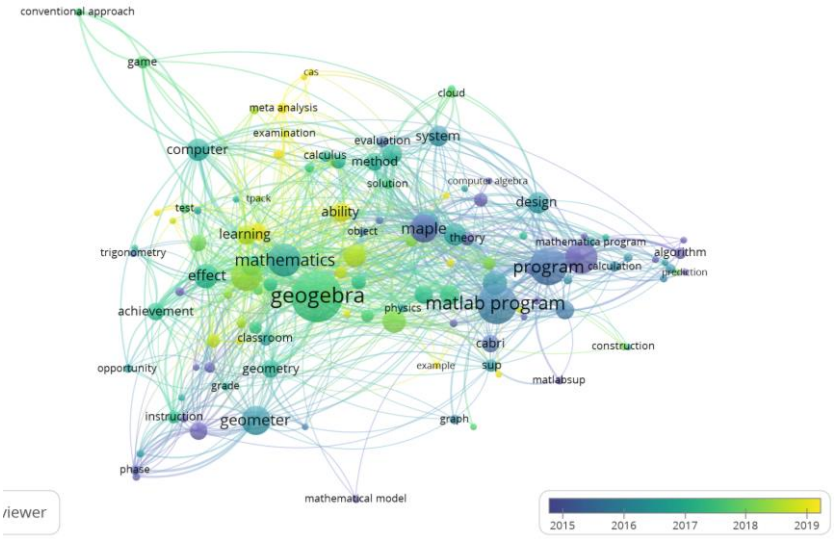

Figure 5. Frames overlay visualization study on the use of CBML

When it is observed in Figure 5 it appears that the trend of research themes related to the use of CBML from 2010 to 2023 is marked with yellow, blue and dark green themes. This means that the themes "development", "meta-analysis", "project", "review" are the latest themes related to the implementation of CBML. While the next theme, the theme that is often researched is illustrated in Figure 6.

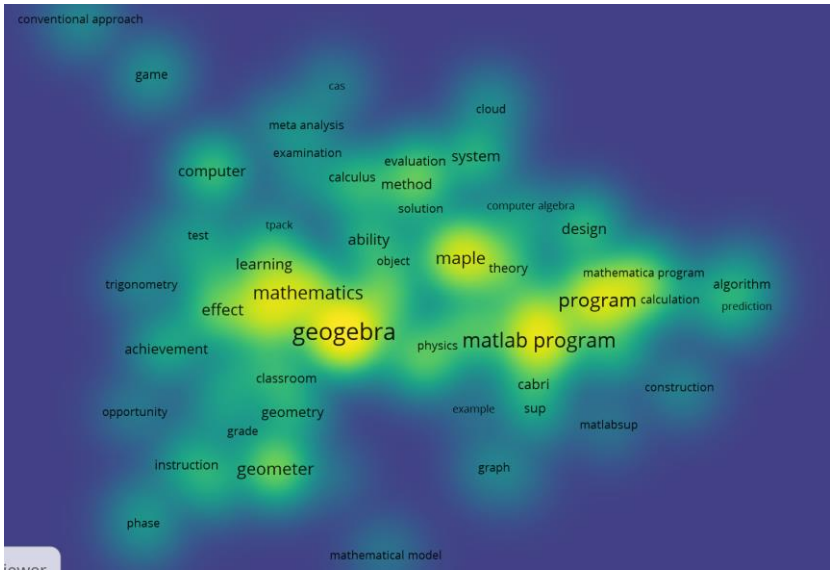

Figure 6. Visualization of CBML study density

Based on Figure 6, the density visualization shows the density or density of the theme studied. A bright yellow color indicates the density of study themes. The lighter the theme color, the more research has been done on that theme. The dimmer the color means that the theme is rarely researched. The themes that often appear are Geogebra, the Matlab program, maple, and

development. While dimly colored themes such as "augmented reality", "altitude," and Tpack" are themes that can be used as references for further research.

The results of the analysis show that the number of documents in Scopus documents varies according to the type of program used. It appears that the Geogebra application is most widely used in learning, followed by Matlab, maple, and cabri applications. This result is in line with the view of Kusumah et al (2020) that Geogebra is more widely used in learning because of its practical use and accommodates algebra and geometry. Whereas other applications, such as winger, only accommodate non-Euclidean geometry, and maxthCAD is complicated to use so it is rarely used in school mathematics. However, each application has its advantages to be utilized in learning mathematics.

Previously, topics or themes often researched include review research such as meta-analysis. The impact of social restrictions due to covid-19 has prompted meta-analytic research related to implementing CBML (e.g, Juandi et al, 2021; Tamur, Kusumah et al, 2021; Tamur, 2021; Tamur, Juandi & Kusumah, 2020). The meta-analytic study is an option because it does not come into direct contact with students but analyzes the results of previous related studies (Juandi & Tamur, 2020; 2021; Yohannes et al, 2021).

Conclusion

This study discusses two main issues, namely the trajectory of the research study and also the identification of important themes and gaps between themes through bibliometric analysis. The findings of studies analyzed from 651 primary studies between 2010 and 2023 suggest the growth trajectory of studies is mediated by the impact of Covid-19. The results of the analysis also show that topics that are rarely studied related to mathematical software are augmented reality, "atitude" and Tpack. This is due to the tendency of studies to look more at the impact on cognitive abilities than on students' affective. This gap will be the basic idea for further ethnomathematics studies.

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Conflicts of Interest

No conflict of interest regarding the publication of this manuscript.

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