

A bibliometric study on mathematical modelling in elementary schools in the Scopus database between 1990-2024

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Abstract

Mathematical modelling is an approach to bridge real-world problems into mathematics as an effort to improve students' mathematical literacy. The purpose of this study is to conduct a bibliometric analysis of published articles related to mathematical modelling in elementary school. This research uses bibliometric analysis method. This study used the Scopus database scanned with the keywords "mathematical modelling" and "elementary school" with a time span of 1990-2024 obtained as many as 78 articles. The data collected was then analyzed using R-software and VOSviewer applications. The results of this study found that the development trend of mathematical modelling research in elementary schools significantly increased after 2015-2023 with a percentage of 67.95%. The top researchers who have the most influence are dominated by authors from Germany and Denmark. Furthermore, in recent years the dominant topics in mathematical modelling research studies in elementary schools such as mathematical modelling cycle, development, mathematical modelling competency, mathematical concept, mathematical knowledge, modeling process, mathematical modelling task, empirical study, and creative thinking. It is hoped that future research can focus on the literature of mathematical modelling carried out on the subject of high school to college level and include analysis on the literature in the years 1960-1990 which is the campaign period and the early years of integrating mathematical modelling into the curriculum of various countries in the world.

Keywords: a bibliometric study, mathematical modelling, elementary schools

INTRODUCTION

Mathematical modelling is a promising research study and learning approach to be implemented at every level of education. Although modelling has been taught informally for centuries, mathematical modelling has only recently emerged formally in education (Spooner, 2024). Campaigns to incorporate mathematical modelling into the curriculum began in the 1960s (Pollak, 2007; Stillman, 2019) and 1970s (Dindyal & Kaur, 2010; Kaiser et al., 2010). Until finally in the 1980s, mathematical modelling was included in the curriculum of several countries in the world such as the United States, the Netherlands, Germany, Australia, Europe, Brazil, Denmark, Singapore, the United Kingdom, and New Zealand (Spooner, 2024; Stillman et al., 2013; Tran

et al., 2020). It shows that mathematical modelling has been accepted at the international level because it has an important contribution to mathematics education (Kaiser, 2020; Stillman et al., 2020a).

The study of teaching and learning mathematical modelling has grown to the extent that it has become a research field in its own right within the mathematics education community (Blomhø, 2019; Stillman & Brown, 2019). However, it was not until the 1990s that mathematical modelling in mathematics education became a research field, where empirical studies began to develop (Niss et al., 2007). Mathematical modelling plays an important role in mathematics education worldwide and has been integrated into curricula and academic standards (Alwast & Vorholter, 2022; Kaiser, 2020).

Contribution to the literature

- This article contributes to the field of education by presenting a comprehensive insight into the topic of mathematical modeling research, especially at the elementary school level, based on the Scopus database for more than three decades (1990-2024).
- Mathematical modeling is a promising learning approach to be implemented at various levels of education, as well as a potential research study topic. Especially for strengthening students' mathematical literacy skills.
- The results of this research analysis can be a valuable reference for policy makers, researchers and academics for future educational practices.

In general, mathematical modelling is understood as the transition or process of translating the context of real-world situations into the mathematical world to be solved (Hartmann et al., 2023; Krawitz et al., 2022; Ledezma et al., 2024) until a reasonable solution is obtained (Stillman, 2019). Mathematical modelling activities begin with a real-world problem situation in which the modeler (or problem solver) uses a mathematical perspective to solve the problem (Chan et al., 2019). Mathematical modelling activities present open-ended problems (Bliss & Libertini, 2019; Caron 2019; Chan et al., 2019; Geiger et al., 2022; Lesh & Zawojewski, 2007; Maaß, 2007).

Modelers can generalize the developed mathematical models to other similar contexts (Chan et al., 2019). Actively carrying out mathematical modelling involves several processes, which are often put together in the form of or described by the so-called mathematical modelling cycle (Jankvist & Niss, 2020; Schukajlow et al., 2023). A now well-known and phenomenal modelling cycle that is the result of DISUM-project is Blum's (2010) 7-step modelling cycle, which is used for cognitive analysis of tasks and also for diagnosing students' real solution processes (Blum & Schukajlow, 2018). The integration of mathematical modelling is expected to be applied to elementary school students (Stohlmann & Albarracín, 2016). In addition to introducing and training students' mathematical modelling process. It also gives experience to students so that they can become independent modelers in solving real situation problems (Fajri et al., 2022).

When looking to conduct research studies related to mathematical modelling, bibliometric analysis can be used as a useful tool to identify trends and scientific evolution of different research fields over a period of time (Cevikbas et al., 2024; Do et al., 2021; Hallinger & Chatpinyakoo, 2019; Lozada et al., 2021; Pham-Duc et al., 2021; Yamaguchi et al., 2023). This method makes it possible to analyze hundreds or even thousands of pieces of literature (Aria & Cuccurullo, 2017). What is very difficult for researchers to do if using the traditional literature review method (Hallinger & Chatpinyakoo, 2019; Öztürk et al., 2024; Prieto-Jiménez et al., 2021). Bibliometrics is an important tool to assess and analyze published scientific literature from a quantitative point

of view (Verma et al., 2021). Helps identify hot research topics and trends (Song et al., 2019). Provides data analysis in the form of citation indices to assess the reputation and influence of specific articles, authors, and research publications (Julius et al., 2021). And predict successful and sustainable research in the future (Geng et al., 2017).

Bibliometric analysis contains many features to map information such as network structure, keywords, publications, references, journals, authors in the research field being analyzed (Aria & Cuccurullo, 2022). In addition, bibliometric analysis provides accurate, reliable, and accountable analysis (Aria & Cuccurullo, 2017; Behl et al., 2022; Cevikbas et al., 2024). Helps gain valuable insights into key topics and emerging trends, thereby guiding future research directions and considerations (Cevikbas et al., 2024). As well as providing promising opportunities in pinpointing research gaps (Schryen & Sperling, 2023). In addition, bibliometric analysis is currently receiving increasing attention as a tool in conducting literature reviews (Öztürk et al., 2024).

Several previous studies have used bibliometric analysis of various research areas such as management (Block & Fisch, 2020; Lin et al., 2024), education and sustainable development (Hallinger & Chatpinyakoo, 2019; Prieto-Jiménez et al. 2021), use of technology in higher education (Díaz-García et al., 2022; Shen & Ho, 2020; Sobral, 2020), social sciences (Mervar & Jokić, 2022; Nasir et al., 2020), STEAM (Jantakun et al., 2024; Karampelas, 2023; Marín-Marín et al., 2021), and mathematics education (Cevikbas et al., 2024; Gokce & Guner, 2021; Julius et al., 2021; Yig, 2022).

But in reality, bibliometric research is still rarely carried out, especially in the field of mathematics education research (Drijvers et al., 2020; Julius et al., 2021). Based on the results of the researcher's review of several literature studies on the Scopus database, Web of Science database, and Google Scholar database, there is no literature study that conducts bibliometric analysis on the topic of mathematical modelling at the elementary school level. Therefore, the purpose of this study is to conduct a bibliometric analysis of published articles related to mathematical modelling in elementary schools

Table 1. Eligibility criteria for inclusion and exclusion review

Category	Inclusion criteria	Exclusion criteria
Language	Documents published in English	Exclude published documents that are not in English
Research fields on Scopus	Research fields include education/research, mathematics, social sciences, and science	Research fields other than education/research, mathematics, social sciences, and science
Type of document	Articles, proceedings, and books	In addition to review articles.
Research subject focus	The review of studies focuses only on mathematics education at the basic education or elementary school level	Reviewing studies at the high school to university level
Database	Documents must be indexed in the Scopus database.	Documents that are not indexed in the Scopus database

in the Scopus database from 1990 to 2024. Specifically, the research questions (RQs) in this study are, as follows:

- RQ1. What is the total volume and growth trend of publications in the mathematical modelling in elementary school literature in the Scopus database from 1990 to 2024?
- RQ2. Which researchers and research groups have the most influence on the mathematical modelling in elementary schools literature in the Scopus database 1990-2024?
- RQ3. Which publication sources had the most impact on the mathematical modelling in elementary schools literature in the Scopus database 1990-2024?
- RQ4. What are the popular research topic trends in mathematical modelling in elementary school literature in the Scopus database 1990-2024?

METHOD

The method used in this research is bibliometric analysis by using the R-software and VOSviewer application tools. In concrete terms, bibliometrics is a research method used to study or analyze research based on scientific publications stored or indexed in big database bibliographies (Gutiérrez-Salcedo et al., 2018). Bibliometric analysis has been recognized as a method that has proven effective in analyzing scientific literature (Do et al., 2021; Ha et al., 2020; Kondrashev et al., 2024; Pham et al., 2023). Bibliometrics is a field of library and information science research that studies bibliographic materials such as research publications, authors, country contributions, and others using a quantitative approach (Verma et al., 2021).

In addition, articles published in scientific journals can be a source of information and data for research such as bibliometric analysis (Kartika et al., 2023). Bibliometric analysis helps researchers identify research trends in a certain period (Do et al., 2021). Which is presented systematically, transparently, and accountability (Behl et al., 2022).

This study analyzed 78 Scopus indexed documents using the help of R-software and VOSviewer applications. The data collection process in this research uses the preferred reporting items for systematic reviews

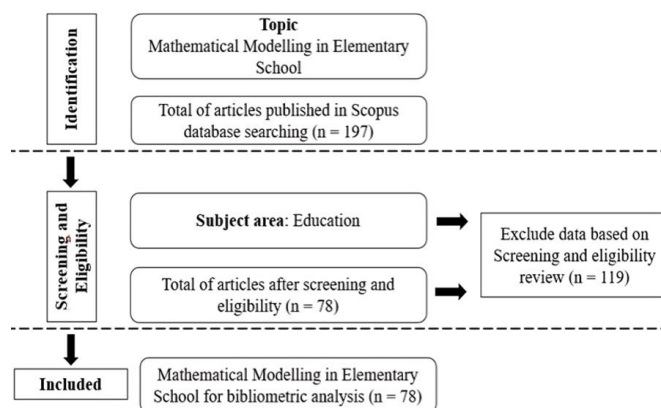


Figure 1. Flowchart of PRISMA procedure in filtering articles for bibliometric analysis (Source: Authors' own elaboration)

and meta-analyses (PRISMA) guidelines as a guide in identification, screening and eligibility, included in the analyzed literature review (Cevikbas et al., 2024; Page et al., 2021). As well as to ensure quality in processing literature searches (Moher et al., 2010). In the identification stage, document searches use the Scopus database with keywords: TITLE-ABS-KEY ("mathematical modelling" and "elementary school") in the time range 1990-2024. The search results obtained 197 documents. The researcher then conducted the document screening and eligibility step: determining and applying inclusion or exclusion criteria (see Table 1) based on the title, topic, abstract and document content. Based on the screening and eligibility results, 119 documents were eliminated because they were not relevant to mathematical modelling and elementary school (Figure 1).

In bibliometric research, the analysis should begin by applying data preprocessing which includes activity steps (Öztürk et al., 2024) such as

- (1) identifying bibliometric analysis techniques appropriate to the purpose and scope of the research,
- (2) determining appropriate software for analysis and visualization, and
- (3) analyzing data and visualizing research findings.

The analysis procedure in bibliometric research (Donthu et al., 2021; Öztürk et al., 2024) is presented in Figure 2.

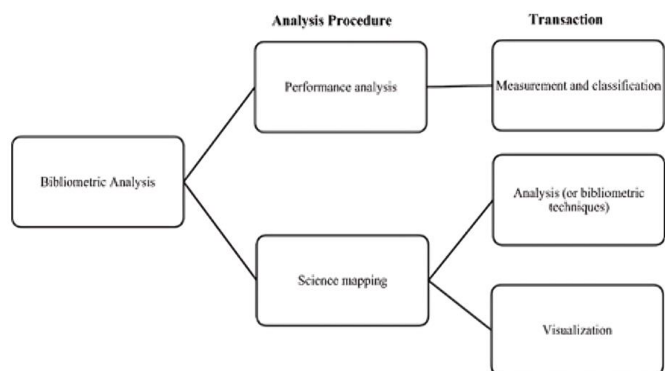


Figure 2. The analysis procedure in bibliometric research (Adapted from Donthu et al., 2021; Öztürk et al., 2024)

RESULTS

RQ1. What Is the Total Volume and Growth Trend of Publications in the Mathematical Modelling in Elementary School Literature in the Scopus Database From 1990 to 2024?

To answer the first RQ, 78 documents on the Scopus database were analyzed, consisting of 63 articles (80.77%), and 15 conferences (19.23%). The development trend of mathematical modelling publications in elementary school from 1990 to 2024 can be seen in **Figure 3**. In 1990-2000 mathematical modelling research in elementary school still did not get much attention as seen in the graph only produced 3 publications. Then the trend of research development experienced a significant increase in 2015-2023 with a total of 53 publications with a percentage of 67.95% of the total 78 documents. Although this trend actually decreased in 2021, it was not too significant. If we look at the graph, in 2024 the trend of research development on mathematical modelling in elementary schools will increase, as evidenced by the beginning of 2024 alone research publications have issued 6 publications.

RQ2. Which Researchers and Research Groups Have the Most Influence on the Mathematical Modelling in Elementary Schools Literature in the Scopus Database 1990-2024?

There have been many studies conducted by researchers on the topic of mathematical modelling in elementary schools. The researchers/authors come from various countries in the world (**Table 2**). It can be seen that of the 10 authors who have the most total citations based on Scopus database articles are dominated by authors from Germany. However, the combined total citation of authors from Germany cannot pass the citation of the authors ranked 1 and 2. The authors who have the most total citation come from Denmark such as Blum, W. (h-index 22) and Niss, M. (h-index 16) both have a total citation of 1,383. In addition, some well-known authors with their research topics on mathematical modelling that are not included in **Table 2** are Krawitz, J. (2 documents), Greefrath, G. (2 documents), Stillman, G. (2 documents), and Leiss, D. (2 documents).

RQ3. Which Publication Sources Had the Most Impact on the Mathematical Modelling in Elementary Schools Literature in the Scopus Database 1990-2024?

Then, the authors identified the main publication sources that have the most impact on the research topic of mathematical modelling in elementary schools. It can be seen in **Table 3** that the 5 sources that have the highest publication documents are International Journal of Mathematical Education in Science and Technology (SJR 2024 = 0.63), Journal of Physics: Conference Series (SJR 2024 = 0.18), and ZDM-Mathematics Education (SJR 2024 = 1.1). Then, the 3 highest sources by total citations are Educational studies in mathematics (SJR 2024 = 1.48), ZDM-Mathematics Education (SJR 2024 = 1.1), Procedia-Social and Behavioral Sciences Development (SJR 2024 = 0).

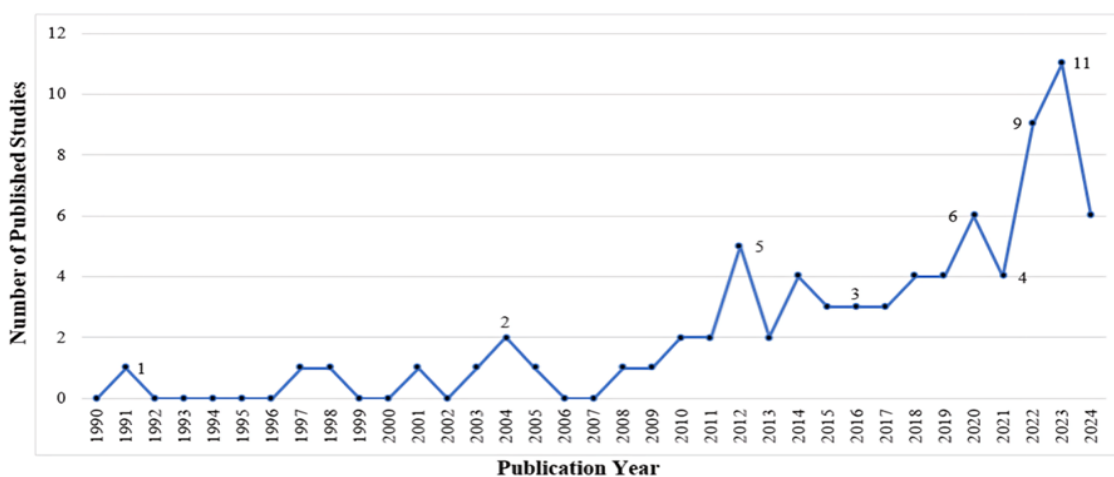


Figure 3. Annual scientific production related to mathematical modelling research in elementary school between 1990 to 2024 (Source: Authors' own elaboration)

Table 2. Top-10 authors by citation of research publications on mathematical modelling in elementary schools between 1990 and 2024

Rank	Author	Affiliation	D	h-index	TC	PYS
1	Blum, W.	Kassel University, Denmark	1	22	1,383	1991
2	Niss, M.	Kassel University, Denmark	1	16	1,383	1991
3	English, L. D.	Queensland University of Technology, Australia	2	31	368	2003
4	Verschaffel, L.	University of Leuven, Belgium	1	51	299	1997
5	Watters, J. J.	Queensland University of Technology, Australia	1	20	252	2005
6	Schukajlow, S.	University of Münster, Germany	5	20	171	2011
7	Kaiser, G.	University of Hamburg, Germany	2	35	141	2022
8	Arseven, A.	Cumhuriyet University, Turkey	1	-	118	2015
9	Cevikbas, M.	University of Hamburg, Germany	1	8	118	2022
10	Stohlmann, M. S.	University of Nevada, USA	3	6	84	2016

Note. D: Documents; TC: Total citations; & PYS: Publication year start

Table 3. Top-7 sources by number of research publications on mathematical modelling in elementary schools and their citations between 1990 and 2024

Rank	Source	Source type	D	SJR 2024	h-index	TC	PYS
1	International Journal of Mathematical Education in Science and Technology	Journal	5	0.63	42	27	2019
2	Journal of Physics: Conference Series	Conference & Proceeding	5	0.18	99	30	2017
3	ZDM-Mathematics Education	Journal	4	1.10	66	130	2018
4	Educational Studies in Mathematics	Journal	3	1.48	83	1,553	1991
5	Eurasia Journal of Mathematics, Science and Technology Education	Journal	3	0.45	56	2	2022
6	Procedia-Social and Behavioral Sciences	Journal	3	0.00	73	84	2009
7	Acta Scientiae	Journal	3	0.20	6	10	2017

Note. D: Documents; TC: Total citations; & PYS: Publication year start

RQ4. What Are the Popular Research Topic Trends in Mathematical Modelling in Elementary School Literature in the Scopus Database 1990-2024?

Based on all 78 documents in the Scopus database that have been analyzed, 486 keywords appear. However, in seeing the relationship between keywords, researchers determined the minimum number of times a keyword appears, which is twice. Based on these criteria, 75 keywords were obtained that fell within the threshold. The results of the co-occurrence analysis from VOSviewer can be seen in [Figure 4](#). The most popular keywords in this research topic are mathematical modelling (77 times), elementary school (36 times), student (17 times), problem (12 times), and teacher (10 times).

The relationship between keywords is based on the size of the circle and the thickness of the path line, which means that the keywords have a strong relationship and often appear together with other keywords. Specifically, when highlighting the keywords mathematical modelling and elementary school, it is seen to have a relationship and co-occurrence with other keywords such as mathematical modelling task (13 times), mathematical modelling activity (13 times), approach/mathematical modelling approach (12 times), modelling problem (8 times), competency (7 times), mathematical application (5 times), real world knowledge (4 times), and creative thinking (2 times).

Furthermore, based on the analysis results shown in [Figure 4](#), obtained information that the most trending keywords currently related to the topic of mathematical modelling research in elementary schools in Scopus database articles from 1990 to 2024 are based on green and yellow nodes such as mathematical modelling cycle, development, mathematical modelling competency, mathematical concept, mathematical knowledge, modelling process, mathematical modelling task, empirical study, and creative thinking. These trending keywords can be considered as one of the alternative variables that can be researched related to the research topic of mathematical modelling which specifically the research subjects are elementary school students.

DISCUSSION

Mathematical modelling is a learning approach that integrates real-life or contextual problems into the learning process of mathematical materials and concepts. The difference between mathematical modelling and other approaches lies in the criteria that the context used must be realistic, authentic, and open-ended. Based on the researcher's review of several literature studies, it is concluded that this research is the first bibliometric research on the topic of mathematical modelling in elementary schools. This study analyzed 78 documents on the Scopus database covering the years 1990 to 2024 on the topic of mathematical modelling in elementary schools. The results have answered 4

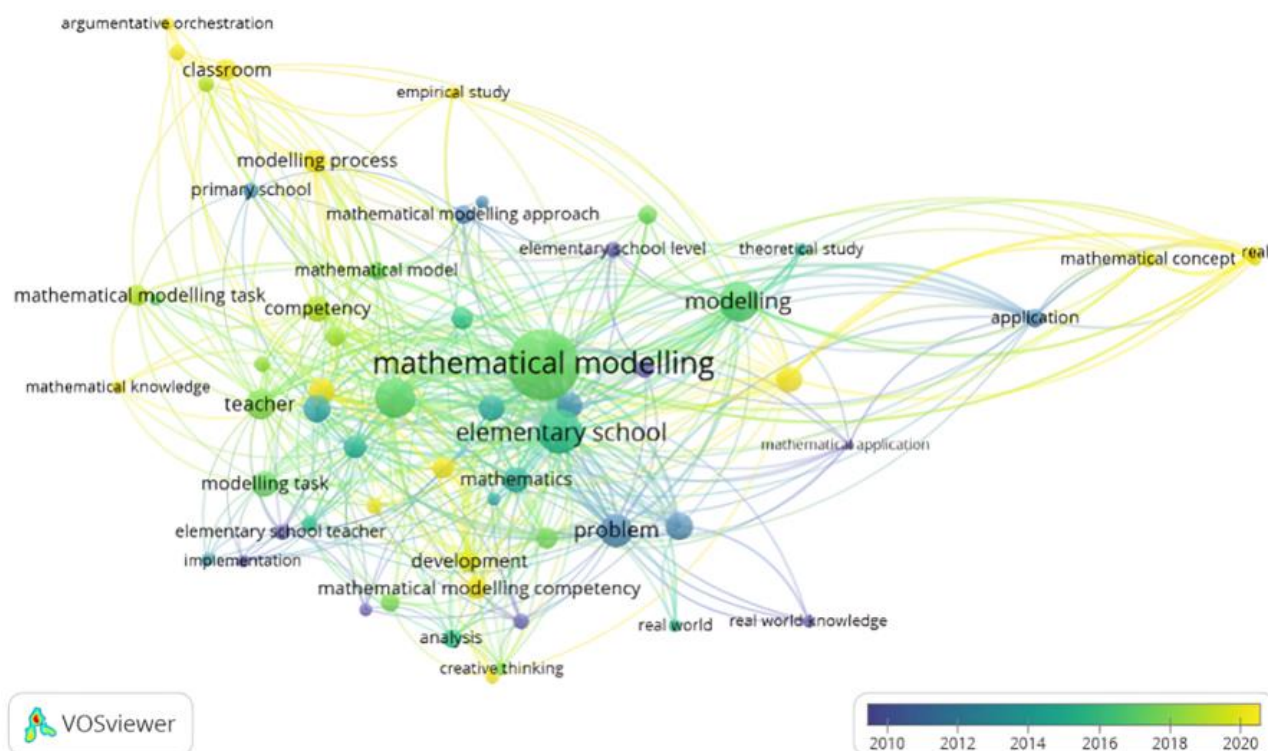


Figure 4. Co-occurrence of keywords on the topic of mathematical modelling research in elementary school between 1990 and 2024 (number of keyword occurrences: at least 2 times, 75 keywords were obtained) (Source: Authors' own elaboration)

questions in this study. Which provides an understanding of the topic of mathematical modelling in elementary school topics such as development trends, researchers who have the most influence, publication sources that have the most impact, trends in hot research topics and guide the direction and consideration of future mathematical modelling in elementary school research variables.

In the results of this study obtained information that the top 10 researchers who have the most influence are dominated by authors from Germany and Denmark. These two countries have become important centers in research literature on the topic of mathematical modelling. This is because mathematical modelling developed through two projects known as KOM-project in Denmark (KOM: Competence and mathematics learning), whose report was published in 2002, has played an important role in this development (Niss & Højgaard, 2019). While in Germany there is the DISUM-project. The starting point of the DISUM-project dates back to 2002 (Blum & Schukajlow, 2018), which was a joint project between mathematics education at the University of Kassel, and educational psychology at the University of Munich (Blum & Leiß, 2007). So it is not surprising that mathematical modelling is highly developed as a research topic by researchers, especially in Germany and Denmark. In addition, the development of mathematical modelling is increasingly accepted at the international level is also supported by the existence of the international community of teachers of mathematical modelling (ICTMA). An international

community that focuses on research on teaching and learning mathematical modelling at all levels of education from early childhood to higher education (Stillman et al., 2020b).

In addition, the current trend of mathematical modelling research topics in elementary schools has become very diverse. These research topics mostly focus on development and design research methods in developing mathematical modelling tasks. Then the current trend of research topics focuses on the purpose of supporting learning activities such as improving mathematical modelling competency, mathematical concept, mathematical knowledge, modelling process, and creative thinking. It is also important to consider data from the World Economic Forum which states that the top three skills in the list of 10 human skills that will become more important in the future are complex problem solving, critical thinking, and creativity (Haara, 2022), which can be enhanced by using a mathematical modeling approach.

Several studies have been conducted on the research topic of mathematical modelling in elementary schools including combining mathematical modelling as a learning environment with the use of virtual manipulatives to help first grade elementary school students to overcome the difficulties detected in their learning related to basic arithmetic operations (Silva et al., 2021), modelling tasks on basic arithmetic operations assisted by artificial intelligence tools (Spreitzer et al., 2024), creating a mathematical modelling lesson based on ethnomathematics in improving creative thinking of

elementary school students (Supriadi et al., 2023), designing mathematical modelling tasks that provide experience in a financial context (Tural-Sonmez & Erbas, 2023), providing mathematical modelling problems to train grade 6 students in building conceptual models and understanding fractions (Shahbari & Peled, 2015).

Integrating mathematical modelling approaches is important to start in elementary school (Stohlmann & Albarracín, 2016). Mathematical modelling is important in domains such as mathematical literacy (Wickstrom & Yates, 2021). The literature shows that competence in mathematical modelling is similar to the competence needed to improve mathematical literacy (e.g., Breakspeari, 2012; Niss, 2015; OECD, 2017, 2018; Steen et al., 2007). The PISA framework focuses on the process of mathematization, the active model building that the KOM-project framework is based on (Berget, 2023). The PISA framework is known as the mathematical modelling cycle (Cai et al., 2016; Stacey, 2015).

Attention continues to be paid to the relationship between the development of mathematical literacy and one's ability to develop and use mathematical modeling to deal with real-world problems using mathematics (Blum, 2002; Haara, 2022). Because the demands of using mathematics to solve real-life problems intersect with what mathematical modeling aims to achieve (Bliss & Libertini, 2019; Mudaly & Dowlath, 2016). For decades, mathematics education leaders have advocated that modeling should be part of the teaching and learning process because of the importance of mathematics in real life (Arseven, 2015; Bonyah & Clark, 2022). So it is important that the education curriculum takes this into account, which can support and prepare learners to live and work in the society of the future (Haara, 2022).

Mathematical modelling is key in developing mathematical literacy skills, as applying mathematics to real-life situations is a core competency of mathematical literacy (Bali et al., 2020; Cevikbas et al., 2022). In addition, integrating mathematical modelling in teaching activities provides experience for students to become independent modelers (Fajri et al., 2022), trains students to use mathematics creatively (Geiger et al., 2018), think critically and develop solutions to world problems (Kaiser, 2017), and motivates students to learn mathematics, appreciate the usefulness and importance of learning mathematics (Stillman, 2019).

CONCLUSION

This literature study analyzes, presents and describes the development of literature on the topic of mathematical modelling in elementary schools over the past three decades. Mathematical modelling is a learning approach that has an important contribution to make in mathematics. Mathematical modelling has gained attention at the international level for its inclusion in mathematics education curricula and also as a promising

research topic. The results of this study show that the development trend of mathematical modelling research has been growing significantly increasing every year, especially starting in 2015.

In this research topic, researchers from Germany and Denmark dominate the top 10 researchers who have the most influence in terms of citations. However, we cannot exclude researchers from the United States, Australia, China, and Singapore who also play a role in publishing literature on mathematical modelling. Especially the research countries that are members of the ICTMA which publishes the development and findings of mathematical modelling in the process of learning mathematics in schools from various countries around the world.

The results of this study have implications for future researchers, teachers, and education policy makers. Based on the four RQs, namely

- (1) the findings regarding the total volume and trend of publication development provide an overview of how mathematical modeling research has developed over time and can be information for anyone in learning about mathematical modeling research from the initial year of publication to the present;
- (2) the findings regarding which researchers have the most influence help teachers and new researchers in finding references of authors to follow. For policy makers, they can find the right researchers to consult in policy making;
- (3) the findings on the source of publications that have the most impact can be a reference source in finding mathematical modeling literature or journal references for research publications on mathematical modeling; and
- (4) findings on research topic trends in the form of popular keywords in mathematical modeling research are useful for other researchers in identifying research topics that they can do in the future.

The limitation in this study is that it only examines the mathematical modelling literature carried out at the elementary school level. It is hoped that future research can focus on the mathematical modelling literature carried out on subjects at the secondary school to university level. In addition, the limitations of this study only investigate the literature in the range of 1990 to 2024. So the researcher excluded the literature in 1960 which was the period of the mathematical modelling campaign to be included in the curriculum and in 1980-1990 which was the initial year mathematical modelling was integrated into the curriculum of various countries in the world.

Author contributions: HMF, AM, and S: conceptualization, methodology, analysis, and investigation of the study; HMF: data collection from the Scopus database, selecting the software for data

analysis, conducting the analysis of bibliometric review results, visualization, and drafting the manuscript; **AM and S:** supervision, critical review, and editing. All authors approved the final version of the manuscript and agreed with its results and conclusions.

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Ethical statement: The authors stated that this study does not require ethics committee approval because the study does not involve human or animal subjects. The study is a review of literature already available in the Scopus database.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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