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Fifty Years of Realistic Mathematics Education Worldwide: Scholarly Impact, Global Reach, and Thematic Development

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ABSTRACT
Despite more than half a century of theoretical development and practical implementation, the global progress of Realistic Mathematics Education (RME) remains insufficiently examined through comprehensive scientometric methods. While earlier studies have qualitatively analyzed RME implementations, a research gap persists in understanding the patterns, themes, and international collaborations that have shaped the RME research field. This study addresses that gap by presenting a large-scale bibliometric analysis of 331 Scopus-indexed publications on RME from 1972 to 2024, offering a new quantitative map of the field's growth, spread, and scholarly impact. The analysis highlights three main developmental phases: a period of modest output before 2010, a steady increase from 2011 to 2018, and a sharp rise from 2019 onward. Major research themes include applying RME in problem-solving instruction, learning pathways, and RME's role in developing student skills and 21st-century competencies. These findings provide empirical evidence of RME's growing academic importance and emphasize its strategic relevance in curriculum reform, mathematics teacher training, and pedagogical innovation.

KEYWORDS
Bibliometric analysis; five decades; quantitative mapping; realistic mathematics education; Scopus.

INTRODUCTION

During the 1950s, a “Math War” broke out, marked by heated crises and debates, a lack of unity about the nature of mathematics and its role in schools, and disagreements over the roles of mathematicians, teachers, parents, and students in mathematical reform. In this context, Dutch mathematics education under the leadership of Freudenthal - the mathematician and mathematics educator who found a way out of the “New Mathematics” movement - with an approach of how to teach well, rather than modernizing the curriculum, led to the formation of the theory (Davison & Mitchell, 2008; Smid, 2020; Treffers, 1993) of Realistic Mathematics Education (RME) (Van den Heuvel-Panhuizen & van Zanten, 2020). Since then, RME has been researched, implemented, and expanded far beyond the Netherlands, reaching more than 30 countries worldwide (Phan et al., 2022).

Recently, RME theory has received increasing research attention from mathematics educators (Phan et al., 2022). Numerous studies have shown the effectiveness of RME theory in contributing to improving problem-solving ability (Son et al., 2020; Yuanita et al., 2018), mathematical communication ability, and mathematical reasoning ability (Chasanah et al., 2020; Nuraida & Amam, 2019; Palinussa et al., 2021), improving mathematical understanding and literacy skills for students (Fauzana et al., 2020; Sumirattana et al., 2017). This shows the vivid development of RME theory in the global community of mathematics educators. Therefore, it is necessary to study and analyze the thematic structure of the RME theory.

The bibliometric analysis method can support this task. While the Scopus database is used to identify topics considered relevant in the field of educational sciences, previous bibliometric analyses of RME, however, have limitations in the use of search keywords. The research conducted by Alp Bayrak and Seher Aslanci (Bayrak & Aslanci, 2022) used keywords that were insufficient for retrieving comprehensive data on this topic. Specifically, the search query (“realistic mathematical education”, “realistic math”, “realistic mathematical education”) overlooked the studies on RME in different versions. The study by Phan et al. (2022) partially addressed this limitation by incorporating a version of the RME developed and implemented in the United States. However, an Indonesian version, known as “Pendidikan Matematika Realistik Indonesia” (PMRI), was still lacking. In addition, the research of Alp Bayrak and Seher Aslanci (Bayrak & Aslanci, 2022) excluded some of the important data, the “classical” studies from the early stages of RME research.

Furthermore, in recent years, especially after the COVID-19 pandemic, there have been no new studies on this topic. Therefore, in this study, the authors analyze data from articles and conference papers indexed in Scopus to examine the growth trajectory, development trends, authors, and influential publications in RME research up to 2024. This includes not only the original RME version but also other variants, such as Mathematics in Context and PMRI. Specifically, this paper addresses the following three research questions:

RQ1: What is the total publication volume and distribution by country and publication time of research works on RME theory worldwide?

RQ2: Which authors, documents, organizations, and primary publication sources (i.e., journal, conference) have the greatest impact on the overall RME research landscape?
RQ3: What are the key topics in RME research?

Realistic Mathematics Education

Starting from the viewpoint of "Mathematics as a human activity" (Freudenthal, 1973), Freudenthal - a Dutch mathematics educator - led Dutch mathematics education in a unique direction, opening the era of Realistic Mathematics Education (Van den Heuvel-Panhuizen & van Zanten, 2020) . Originating in the Netherlands, the RME theory has developed into one of the most extensively researched and implemented theories in mathematics education worldwide (van den Heuvel-Panhuizen, 2020). Freudenthal proposed an approach based on RME theory in his groundbreaking work "Mathematics as an Educational Task," from the basic point of view of "mathematics as a human activity," and presented the thesis of guided rediscovery, as well as how to organize a field of knowledge through mathematization (Freudenthal, 1973). This is considered one of the first bricks for the theoretical foundation of RME.

Continuing this line of thought, Van den Heuvel-Panhuizen elaborated more on the RME approach, stating that "Realistic Mathematics Education" - hereafter abbreviated as RME-is a domain-specific instruction theory for mathematics, which has been developed in the Netherlands. A characteristic of RME is that rich, "realistic" situations are given a prominent position in the learning process. These situations serve as a source for initiating the development of mathematical concepts, tools, and procedures, and as a context in which students can, at a later stage, apply their mathematical knowledge, which then gradually becomes more formal, more general, and less context-specific. Although "realistic" situations in the meaning of "real-world" situations are important in RME, "realistic" has a broader connotation here. It means students are presented with problem situations they can imagine. This interpretation of "realistic" traces back to the Dutch expression "zich REALISEren," meaning "to imagine" (Van den Heuvel-Panhuizen & Drijvers, 2014).

The theoretical framework of RME encompasses six fundamental instructional principles: The activity principle, the reality principle, the level principle, the intertwinement principle, the interactivity principle, and the guidance principle (Van den Heuvel-Panhuizen & Drijvers, 2014). First, the activity principle emphasizes students' active role in the process of mathematization, whereby they construct knowledge rather than passively receive it (Van den Heuvel-Panhuizen & Drijvers, 2014). The reality principle asserts that learning should begin with meaningful situations that are experientially real or imaginable, thereby providing a foundation for the reinvention and application of mathematical concepts (Vos, 2020). The level principle emphasizes that learning advances through various stages, from informal strategies to more formal and abstract reasoning, with models acting as a bridge between "models of" specific situations and "models for" broader mathematical thinking (Doorman & Gravemeijer, 2009). In addition, the intertwinement principle emphasizes the integration of different mathematical domains, enabling learners to apply knowledge across contexts flexibly. The interactivity

principle views learning as a social process in which discussion and argumentation play a crucial role in fostering deeper understanding (Van den Heuvel-Panhuizen & Drijvers, 2014). Finally, the guidance principle underscores the teacher's role in supporting students through a process of guided reinvention, based on carefully designed learning trajectories that facilitate the gradual construction of mathematical knowledge (Gravemeijer & Doorman, 1999).

This theory contributed to resolving the debates of mathematicians and mathematics educators in the 1960s (Van den Heuvel-Panhuizen, 1996). RME is the basis for guiding teachers in finding and creating paths, and in designing mathematical situations, contexts, and tasks so that Mathematics becomes more attractive, more accessible in school, and more "real" for students (Bonotto, 2009; Laurens et al., 2017). Mathematics in schools will both ensure its scientific nature and become more closely tied to real life. Students will find it easier to access and apply mathematics in their daily lives. At the same time, there has been strong theoretical development in the theory of education, particularly in constructivism (including social and radical constructivism), and RME is regarded as a constructivist theory and model in mathematics education (Gravemeijer, 2020). This theory also shares features with Didactic Situation Mathematics (DSM) in its consideration of learning situations that can stimulate interest and create opportunities for students to explore and construct knowledge (Nguyen et al., 2019).

Beyond the borders of the Netherlands, the RME has independently reached more than 32 countries and territories across different continents (Phan et al., 2022; Van den Heuvel-Panhuizen, 2020). RME is seen to come to the U.S. from the collaboration between researchers at Utrecht University's Freudenthal Institute and the Center for Mathematical Science Education Research at the University of Wisconsin-Madison, to the establishment of the Freudenthal Institute United States (FIUS) on RME at the University of Wisconsin-Madison in 2003 (Webb & Peck, 2019). The influence of RME in the United States is clearly evident in context-based math education programs and materials called "Mathematics in Context" (MiC) (Van den Heuvel-Panhuizen, 2003). Meanwhile, in Indonesia, given the special historical relations with the Netherlands, deep professional cooperation between the two countries has led to the creation of a special edition of Indonesia Realistic Mathematics Education, known as "Pendidikan Matematika Realistik Indonesia" (Zulkardi et al., 2019).

Not only in the US or Indonesia, with Freudenthal's prestige and the attractiveness of RME, but this theory has also contributed to the innovation of mathematics education in many countries at different levels, such as China, the UK, Singapore, Canada, Belgium, South Africa, ... (Phan et al., 2022). The power of RME has transcended the boundaries of its cultural context (Van den Heuvel-Panhuizen & van Zanten, 2020).

Like every educational theory, the application of RME is also marked by challenges as well as many recommendations. For example, in RME theory, the teacher's knowledge of context affects their ability to design contexts and tasks for students (Barnes & Venter, 2008). The organization of teaching according to RME requires significant effort and time from

teachers, and it is sometimes difficult to prevent students from losing concentration on the mathematical content, which can lead to a loss of attention to the mathematical knowledge and logic they deserve (Wittmann, 2005). However, according to Phan et al. (2022), RME remains a theory that is being researched and applied in many countries worldwide.

METHODOLOGY

The bibliometric research method, although it emerged in the field of library studies, is increasingly popular and widely applied across many studies in education and other fields (Hallinger & Kovačević, 2019; Pham et al., 2021). In addition to exploring the intellectual structure of a topic, this method can indicate the distribution by country, analyze prominent trends, identify influential authors, and examine the academic connections among research works (Tong et al., 2023).

VOSviewer software is a suitable and reliable tool for identifying topics, analyzing academic networks, and forecasting research trends. Firstly, the software is specifically designed for scientific mapping, with a transparent data standardization process that enables result reproducibility and the objective measurement of a field's knowledge structure (van Eck & Waltman, 2009). Secondly, VOSviewer has been widely used in educational research as a powerful bibliometric tool to analyze intellectual frameworks, emerging research themes, and long-term development trends. By employing science mapping techniques, previous studies—especially in educational administration (Hallinger & Kovačević, 2019), STEM education (Ha et al., 2020), and mathematics education (Cevikbas et al., 2024)—have effectively identified influential scholars and countries while illustrating complex collaborative networks within the field.

This section presents the process of building and refining a dataset and examining its contents.

Identify data sources

Scopus, Web of Science, and Google Scholar are the most popular sources in the academic community. Google Scholar, a web-based database, is effective at retrieving information about documents. Meanwhile, Scopus and the Web of Science have an advantage in evaluating performance through citation analysis (Falagas et al., 2007). Clarivate Web of Science (WOS) is also used by some authors in analyses (Durán-Sánchez et al., 2017; Fabregat-Aibar et al., 2019). However, in education, Scopus is better suited because Scopus is significantly broader in scale than Clarivate WOS (Hallinger & Kovačević, 2019).

Data collection

The data collection for the study is conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which aims to ensure the quality of the literature search process (Moher et al., 2010).

To overcome the limitations of keywords used in previous studies, this research expands the search terms to gather more resources, enabling more detailed information and a more

thorough exploration of the topic. In addition to the original term "Realistic Mathematics Education" or "PMRI" terms, and the analyzed term "Mathematics in context," other phrases used by mathematics education researchers are also included, such as “realistic mathematics approach” (Kindangen et al., 2021; Wahyuni & Kusumah, 2023), “realistic mathematical learning” (Mardiana et al., 2020), and “realistic mathematical approach” (Sipayung et al., 2021). Therefore, the criteria for the document search, based on the study's scope, are presented in Table 1 below.

Table 1.

Variables and inclusion criteria

Variables	**Inclusion Criteria**
Databases	Renowned international databases: Scopus.
Keywords	"realistic mathematics education") OR ("realistic mathematic education") OR ("realistic math*") OR ("mathematics in context") OR ("math in context") OR ("maths in context") OR ("Pendidikan matematika realistik Indonesia") OR ("PMRI"))
Year of publication	< 2025.
Document type	Conference paper, article
Area of research	Social sciences.
Language	English

The dataset obtained after the query continues to be included in the filtering process according to the following steps:

Step 1: With the above query structure, a dataset of 353 documents was obtained. We conducted duplicate data filtering. In this step, we excluded one document by (Septiany et al., 2015). After step 1, the data is 352 documents.

Step 2: Review and check the summary and keywords of the documents. If any document lacks an abstract or keywords, we visit the website or search the document's full text to add a summary and keywords. For example, some documents were supplemented with summaries (Cooper, 1998; Davis, 2017) and keywords (Cooper & Harries, 2002; Stephan, 2014).

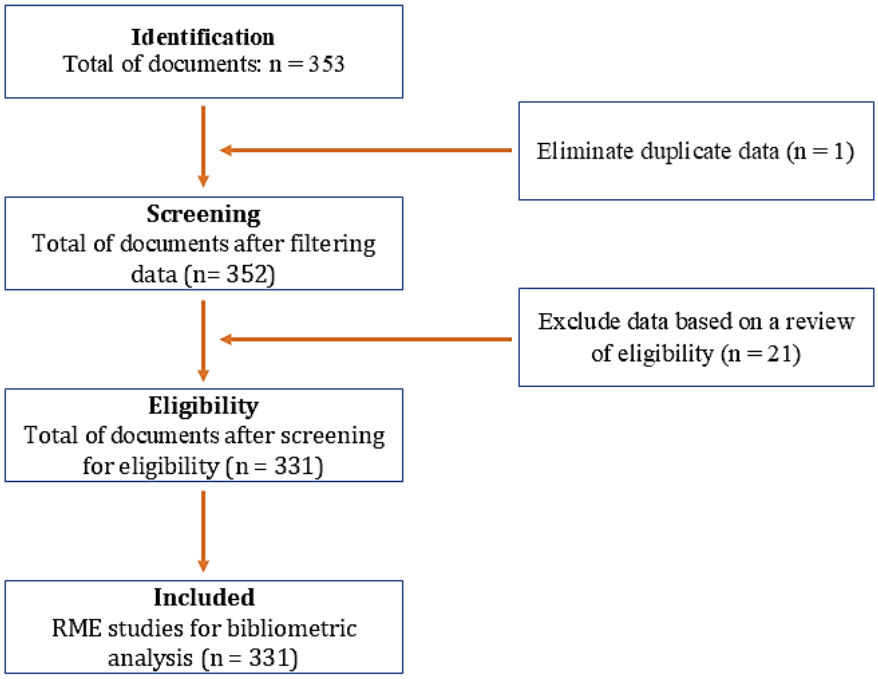
Step 3: Analyze each document by reading the title, summary, and, when applicable, the full text of the article. Each member was responsible for reading, making recommendations, and, as a group, discussing the reasons for keeping or removing certain documents from the dataset. Studies that used bibliometric analysis or review were excluded from the data; specifically, we excluded documents (Phan et al., 2022; Prahmana et al., 2020; Tümkaya & Ulum, 2020; Trinh et al., 2022). Documents that did not match the search terms were also removed, including articles containing the keyword PMRI but referring to other meanings, such as "Parallel Magnetic Resonance Image"—a term for parallel magnetic resonance imaging in medical processing techniques (Inam et al., 2019; Tran et al., 2010). Similarly, articles with the phrase "realistic

mathematical model" that did not pertain to the RME method but involved mathematical models in fields like corporate auditing (Wang et al., 2022), drone studies (Kim & Kim, 2022), or wind energy research (Jiménez-Santín et al., 2023) were excluded. In this step, we eliminated all 21 documents.

The screening process is shown through the PRISMA Diagram in Figure 1 below:

Figure 1.

The PRISMA chart shows the process of collecting and shrinking the dataset of RME studies extracted from the Scopus database



After filtering, the dataset yielded 331 documents. Next, the research team added information on the level of each document, based on the classification frameworks of Pham et al. (2024) and Vuong et al. (2020), with the following levels: Higher education, Upper secondary education, Lower secondary education, Primary education, Preschool education, and General.

To classify educational levels for the initial set of documents, the titles and abstracts were examined. For example, the study by Armiati et al. (2022) includes the keyword “eighth-grade students” in the title, and Reinke et al. (2024) include the keyword “7th-grade” in the abstract; therefore, they were categorized as lower secondary education. Similarly, the study by Rusiyanti et al (2022) includes the term “high school” in the title and was thus classified as upper secondary education. Studies on policy or general curricula that are not specific to any educational level were categorized as general, such as the study by Nguyen et al. (2020) or the study by Van den Heuvel-Panhuizen and Wijers (2005). For documents in which the educational level could not be determined from the title or abstract, the full text was reviewed, and the research team reached a consensus decision. For instance, the study by May (1972) was classified as general, while the study by Šipuš et al (2022) was categorized as upper secondary education. After this process, the final dataset used for analysis includes 331 documents.

Data Analytics

The bibliometric review with the queried dataset was saved in a Microsoft Excel file. The file contains 331 profiles suitable for analysis, including the author's name, author's link, document title, source type, document summary, keywords, citation count, year of publication, and references.

Descriptive statistics were performed using Microsoft Excel to count quantities of specific objects. The bibliometric analysis was conducted with VOSviewer software version 1.6.16.

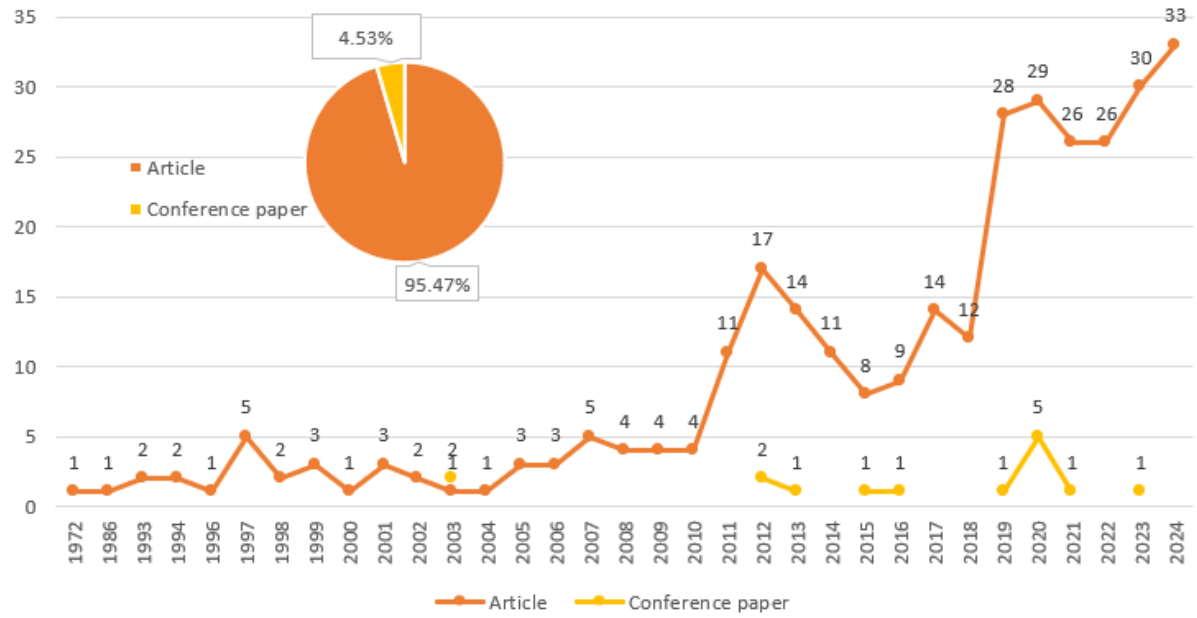
RESULTS

RQ1: What is the total publication volume and distribution by country, publication time of research works on Realistic Mathematics Education (RME) theory in countries around the world?

The PRISMA search and identification process narrowed down to 331 RME-related documents, of which 316 articles (95.47%) were published in 83 journals and 15 conference papers (4.53%) were published in 12 workshops (Figure 2). 1972 was the first year that an article on RME – an article by May Kenneth O – was published and indexed in the Scopus database (May, 1972).

Figure 2.

Number of RME-related publications by type from 1972 to 2024



Based on the timeline, the number of publications can be divided into 3 phases of research development on RME theory as follows:

Phase 1: From 1972 to 2010, mathematics educators paid little attention to RME theory, as reflected in the 39-year period, which yielded only 50 papers and conference materials. The research volume on RME theory remained quite small, with only 1-5 documents indexed in Scopus each year.

Phase 2: From 2011 to 2018, mathematics educators have had a certain interest in RME theory. Within 8 years, 101 documents were published in the Scopus database, doubling the number of

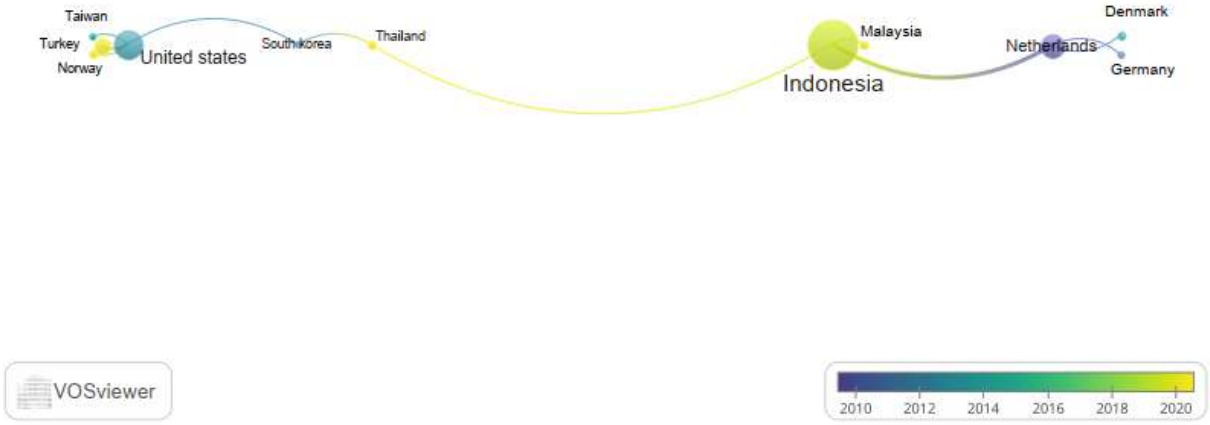
publications in 39 years in Phase 1. At this stage, the fewest documents were published in 2015, with 9, and the most in 2012, with 19.

Phase 3: From 2019 to 2024: This period saw a surge in documents related to RME theory, with 180 documents over the 5 years. Every year, more than 20 documents are published. In 2020, 34 documents were published and indexed in the Scopus database.

In terms of geographical distribution, an analysis of 331 documents identified 319 authors from 47 countries. From the data in Table 2 (*see appendices*), a significant geographical imbalance can be identified: 247 documents on RME (accounting for over 74.62% of the total documents published in the Scopus database) come from three countries: Indonesia, the United States and the Netherlands; the number of documents from the remaining 44 countries accounts for only 25.38% of the total publications published in Scopus database. Indonesia has the highest number of articles in journals and conference reports, as well as the largest number of citations in this field: 160 documents (48.34% of the total) corresponding to 1387 citations. In second place is the United States with 52 documents – 1172 citations, and in third place is the Netherlands with 35 documents – 1074 citations. Turkey, the United Kingdom, Australia, Vietnam, and South Africa have from 9 to 13 published documents.

Figure 3.

Co-authorship – Country – Minimum number of documents of a country: 3 –Minimum number of citations of a country: 2



The size of the nodes indicates the number of publications (Figure 3). Therefore, this figure shows that although the Netherlands is the birthplace of RME, Indonesia has the highest number of publications, followed by the United States. At the same time, these three countries also play a central role in international cooperation among three prominent groups of nations. However, there is no cooperation between the Netherlands and the United States. Additionally, a relationship between countries is expressed through four clusters: the first cluster includes four countries—the United States, Turkey, Norway, and Taiwan; the second cluster includes three countries—the Netherlands, Germany, and Denmark; the third cluster comprises two countries—Indonesia and Malaysia; and the fourth cluster consists of two countries—South Korea and Thailand. The lighter-colored nodes in Figure 3 show the recent ongoing development

and influence of RME in several countries, including Indonesia, Malaysia, Thailand, Turkey, and Norway.

RQ2: Which author, document, or primary publication source (i.e., journal, conference) has the greatest* impact *on the RME overview?

Table 3 (*see appendices*) lists the 24 authors whose research on RME has received the highest number of citations in both the dataset and Scopus. These 24 authors come from 16 institutions, including Freudenthal Institute, Université Paris Diderot-Paris 7, Roskilde University, Universität Zürich, San Diego State University, Seoul National University, University of Pattimura Ambon, State University of Malang, University of Leuven, University of North Carolina Charlotte, Middle East Technical University, Arizona State University, Bandung, Lambung Mangkurat University, University of Crete, and Stanford Graduate School of Education. They are located in 11 countries, including the Netherlands, France, Denmark, Switzerland, the United States, South Korea, Indonesia, Belgium, Turkey, and Greece.

Of the 24 most prominent authors, 6 have more than 2,000 citations in Scopus. In particular, the three most highly cited authors, with more than 200 citations in the analytical data system (Location Cited) and more than 1000 citations in the Scopus data system, are Van den Heuvel-Panhuizen Marja, Gravemeijer Koeno, and Doorman Michiel.

The most cited study is "The didactical use of models in realistic mathematics education: An example from a longitudinal trajectory on percentage" (Van den Heuvel-Panhuizen, 2003) with 251 citations; the second is the article "Context Problems in Realistic Mathematics Education: A Calculus Course as an Example"(Gravemeijer & Doorman, 1999) with 245 citations and the third is the article "Conceptualizing inquiry-based education in mathematics" with 181 citations (Artigue & Blomhøj, 2013) (Table 4, *see appendices*).

Table 5 (*see the appendices*) lists the 10 organizations with the most publications. In the list of ten organizations with the most research published on the Scopus database on RME, five are based in Indonesia, namely Sriwijaya University, Ahmad Dahlan University, Universitas Pendidikan Negeri Padang, University, and Universitas PGRI Semarang; while three institutions are from the United States: San Diego State University, Portland State University, and Arizona State University. Sriwijaya University leads in number with 59 articles; Utrecht University, together with the Freudenthal Institute in the Netherlands, ranks second with 34 publications and holds the highest citation count of 1,064.

Table 6 (*see appendices*) lists the 13 journals/publishers with the highest number of RME-related articles (5 or more) out of 93 publishing sources. In terms of the number of publications, the top six sources include: Journal on Mathematics Education (65 publications), Journal on Mathematics Education (21 publications), Journal of Mathematical Behavior (20 publications), International Journal of Scientific and Technology Research (20 publications), Mathematics Teaching-Research Journal (17 publications), Educational Studies in Mathematics (15 publications). Meanwhile, in terms of the number of citations, the top six sources are: Educational Studies in Mathematics (832 citations), Journal on Mathematics Education (700

citations), Journal of Mathematical Behavior (592 citations), ZDM-International Journal on Mathematics Education (501 citations), Journal for Research in Mathematics Education (272 citations), and Mathematics Education Research Journal (133 citations).

RQ3: What are the most important topics in the RME literature?

The study by Phan et al. (2022) analyzed the main keyword "RME". In this study, we examined the keywords of the studies from two perspectives: RME and PMRI.

In order to analyze the research topics from the keywords in the dataset, we first identify several keywords with overlapping meanings written in different forms such as: realistic mathematics education, realistic mathematic education, realistic mathematics, realistic mathematics education (RME), RME is homogenized into RME; or curricula and curriculum; fractions and fractions; learning trajectory, learning trajectories and learning sequences; problem solving, problem-solving, etc. are also carried out uniformly. As discussed above, in Indonesia, RME has evolved into a distinct localized version. Accordingly, to elucidate the characteristics of RME-related research in this context, keywords such as PMRI, Indonesia Realistic Mathematics Education (IRME), and Pendidikan Matematika Realistik Indonesia in some documents, such as (Kristiani et al., 2024; Mariana & Sasmita, 2024; Putri et al., 2022), are unified into PMRI. We then run the keyword analysis on VOSViewer version 1.6.16. The data analysis shows that, of the 917 keywords, the most frequently occurring are presented in Table 7 (*see appendices*).

The keyword PMRI (42 times) appears at the 3rd-highest frequency after the main terms RME (146 times) and Design research (45 times), which confirms that RME in Indonesia has once again received strong attention and promotion in research and the implementation of mathematics education.

The research topics on RME theory analyzed in Figure 4 include 33 keywords with at least five occurrences to form six main clusters, which are: Cluster 1 (calculus, context, differential equations, mathematical model, mathematics, mathematics instruction, problem solving, proportional reasoning, undergraduate mathematics); Cluster 2 (conceptual knowledge, design research, fractions, learning environment, mathematical knowledge, numeracy, PMRI, primary education); Cluster 3 (abstract algebra, creative thinking ability, ICT, mathematization, reinvention, RME, teaching and learning); Cluster 4 (algebra education theories, learning trajectories, mathematics education, middle school, students); Cluster 5 (Addie, Critical Thinking Skill); and Cluster 6 (Teacher Education).

The number of studies is 110 at the primary level, 112 at the lower secondary level, and 29 at the upper secondary level (Figure 5). Studies on RME focused mainly on the primary and secondary levels, with 222 of 321 (69.16%).

Figure 4.

Science Mapping of Author's Keywords based on Co-occurrence Analysis of all Keywords in RME - PMRI between 1972 and 2024

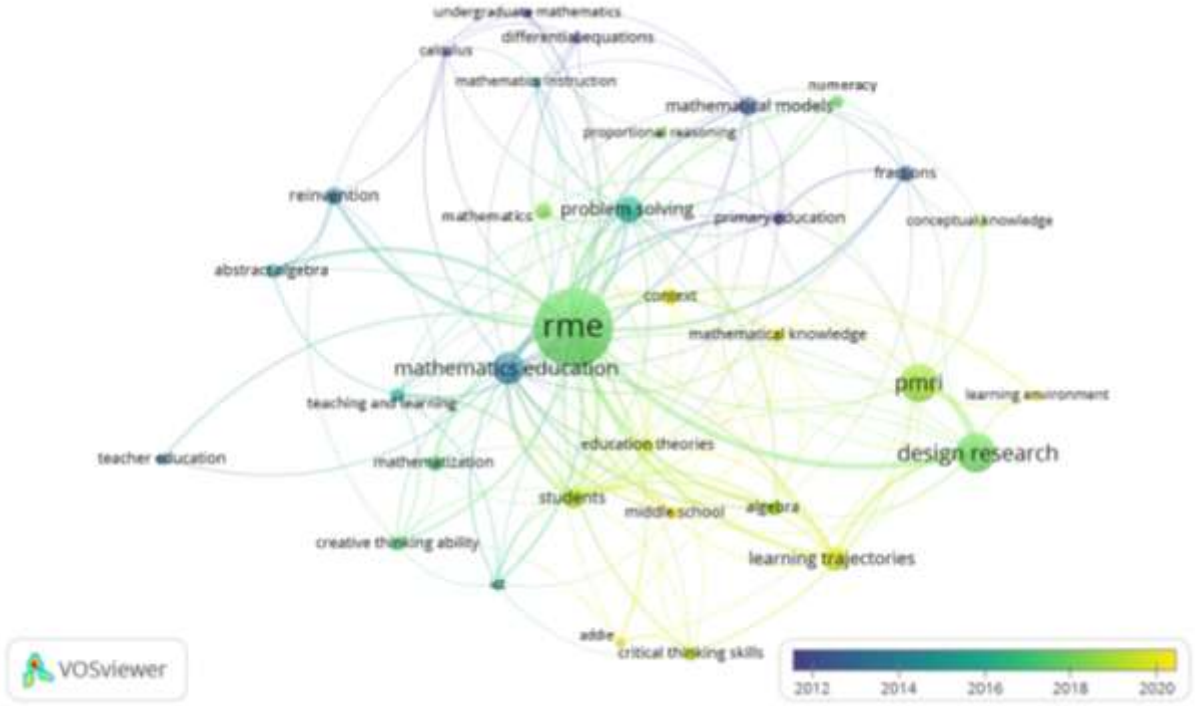
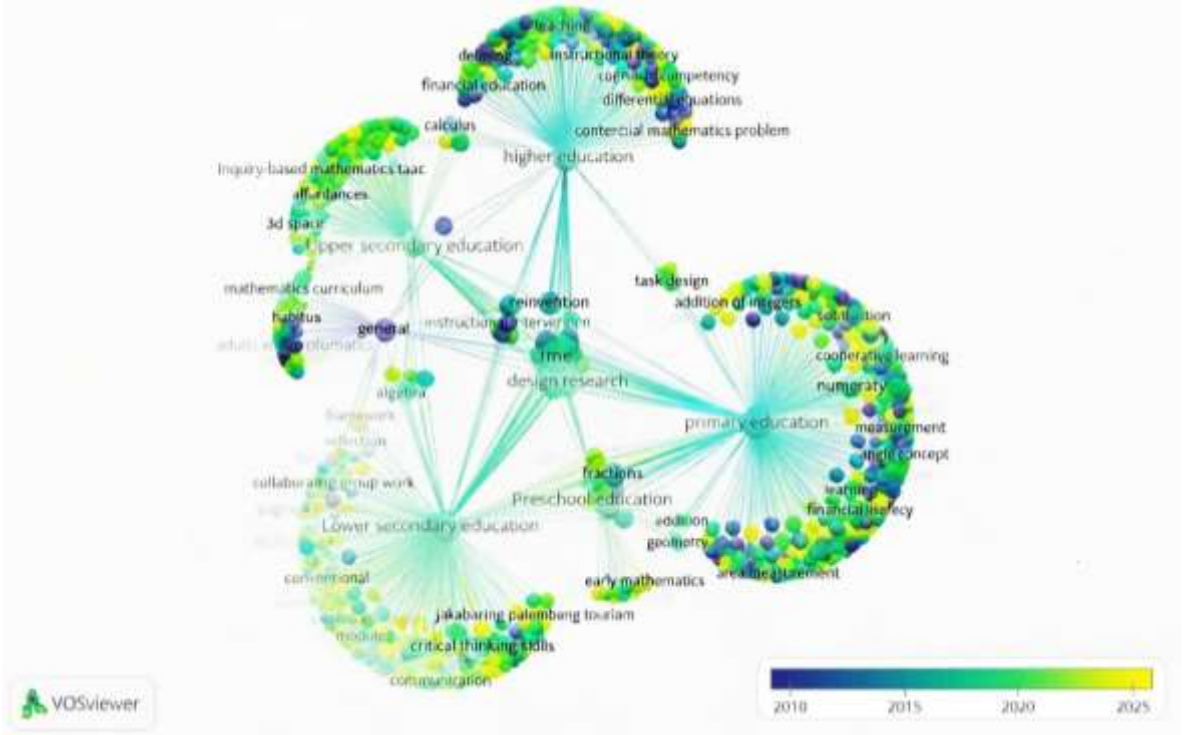


Figure 5.

RME Document Analysis by Educational Level



In addition, research materials at the primary level are associated with keywords on the content of financial knowledge (Sawatzki, 2016; Sawatzki & Sullivan, 2017; Sawatzki et al., 2019) ; measurement, fractions, statistics (Bayu et al., 2023), and especially the issue of national

culture (Revina & Leung, 2019; Rezeki et al., 2021; Winarti et al., 2012). Keywords such as abstract algebra, algebra, and critical thinking indicate that these topics are important in middle school mathematics education. Prominent keywords such as calculus and differential equations indicate that studies applying RME theory to the knowledge content of these subjects are widely conducted (Rasmussen & Blumenfeld, 2007; Rasmussen & Marrongelle, 2006; Riyanto et al., 2017). Keywords such as technology, lesson study, and pre-service teachers reflect research on undergraduate mathematics teaching, particularly in teacher education and the application of technology in teaching.

In addition, keywords such as technology and ICT indicate that the integration of information technology in mathematics teaching is becoming increasingly significant, especially in teaching through digital platforms, as shown in studies such as Fesakis et al. (2018) and Zaranis (2018).

DISCUSSION

Research on RME has gained significant attention from scientists, leading to a surge in publications and wider geographic coverage across many countries during phases 1 and 2. In these phases, the number of papers involving Indonesian mathematics educators represented a substantial portion (phase 2: 49/101, 48.51%; phase 3: 79/136, 58.09%). These achievements result from programs and projects in collaboration between Indonesia and Utrecht University, the Netherlands, aimed at implementing, disseminating, and promoting RME theory in Indonesia. Such efforts include the Netherlands Program for the Institutional Strengthening of Post-Secondary Education and Training Capacity (NPT); PMRI Dissemination Project (Do - PMRI); International Master's Program of Mathematics Education (IMPoME); International Conference on Design Studies (SEA-DR); the Mathematical Literacy Competition (KLM) Project; the Indonesian Context-Based Mathematics Task Project (CoMTI); the Practical Mathematics Education Course for Middle School Mathematics Teachers in Southeast Asia (SEA-RME Course) (Phan et al., 2022; Zulkardi et al., 2019). These accomplishments have been strongly supported by the Indonesian government's solid policy focus on adopting and institutionalizing RME as a nationwide framework for mathematics curriculum reform, teacher education, and research development (Zulkardi et al., 2019). Consequently, Indonesia has experienced a notable increase in international publications on RME-related topics, reflecting the expanding scholarly and practical influence of this approach.

The three countries that stand out across the three research clusters are also those with the highest number of publications: the Netherlands, the birthplace of RME theory, and the United States and Indonesia, which each have their own versions of RME—Mathematics in Context and PMRI, respectively. This finding highlights interesting trends concerning the countries involved in RME research. The strong collaboration between the Netherlands and Indonesia is a positive sign of international exchange and the application of RME theory in various educational settings, including Indonesia's local frameworks. The absence of a similar

connection between the United States and the Netherlands could be seen as an untapped opportunity for exchanging ideas and methods. However, it could also be due to the types of publications studied—mainly articles and conference reports—which may not fully represent the extent of collaborations, or it could indicate that RME research in the U.S. is still developing or less centered on the Dutch-based theory.

The phenomenon of a few countries dominating scientific research in a specific field, whether by citations or publication volume, is quite common. For example, in educational administration, Hallinger & Kovačević (2019) found that research output from the United States, the United Kingdom, Canada, and Australia makes up the majority of global publications. Similarly, in STEM education within the ASEAN region, Ha et al. found that Malaysia leads in the number of publications, followed by Thailand and Indonesia (Ha et al., 2020). Therefore, Indonesia's dominance in research publications on RME is not unusual from a bibliometric perspective. This prominence can also be linked to the long-standing collaboration between the Netherlands and Indonesia in establishing and developing Indonesia's mathematics education program based on RME theory. However, such dominance might introduce geographical bias, as most empirical studies are conducted within specific educational contexts. At the same time, this situation highlights both the vitality and influence of RME, as well as opportunities for expansion and exploration, especially regarding how a European educational theory has been adapted in culturally diverse contexts such as Indonesia. Future research could investigate the contributions, innovations, modifications, or even "deviations" from the core principles of RME when applied under particular conditions. Cross-cultural and replication studies, in particular, could provide valuable insights into how RME develops beyond its country of origin, the Netherlands. Increasing international collaboration in RME research could also help reduce geographical bias and broaden the global understanding of the theory.

In addition, the top three most-cited authors, including Van den Heuvel-Panhuizen Marja, Gravemeijer Koeno, and Doorman Michiel, are all Dutch researchers from the Freudenthal Institute at the University of Utrecht – a well-known center specializing in research and development in mathematical education. Especially, this is the cradle of the original research on RME theory. Their publications, from 1994, 1996, and 1999, represent the early stages of the development of the RME theory and form the basis for further research on this topic. This is partly explained by their publications, which have made fundamental contributions to the theoretical framework and initial concepts of RME theory, providing a basis for further research. Moreover, these authors are also influential and prestigious scientists in the RME research community.

The two most influential studies in the early stages of the Practical Mathematics Teaching (RME) theory were conducted by three prominent authors. These foundational works later shaped the direction of RME research and are often cited in teacher training materials. The first, most cited, is an article by Van den Heuvel-Panhuizen (2003), published in *Educational Studies in Mathematics*, which describes how to use the model in RME for students to self-explore the

concept of percentages through real-world situations. A second study by Gravemeijer & Doorman (1999) highlighted the importance of contextual mathematical problems at the start of the learning process, as demonstrated by the Calculus course. This work pioneered the extension of RME to high school mathematics, rather than being limited to primary or secondary school.

Research on RME theory is published by researchers from prestigious organizations around the world (Sriwijaya University, Utrecht University, Freudenthal Institute, Portland State University, ...) and by leading journals in the field of mathematics education (Journal on mathematics education (JME), Journal of mathematical behavior (JMB), ... This shows the interest of the mathematics education community in this research topic as well as the influence of the topic on the development of mathematics education theory.

Sriwijaya University and Pendidikan University are the first and leading universities in Indonesia to implement RME research from the Netherlands into Indonesian education in teaching mathematics at the primary and secondary levels. These are two universities that have close cooperation with Utrecht University and the Freudenthal Institute in mathematics education research (Prahmana et al., 2020). Pendidikan University, considered a leading center for RME theory and RME researcher training, has trained numerous master's and PhD students in RME theoretical research. It is the birthplace of leading scholars in mathematics education in Indonesia (Zulkardi, 2002). Meanwhile, Portland State University in the USA is a site for collaborative research with Dutch scholars under *the Mathematics in Context* program.

According to statistics, the two journals with the most publications on RME are the JME Journal (Journal on Mathematics Education) and the Mathematics Education Journal (MEJ). Both belong to the same organization, Sriwijaya University of Indonesia. JME is the first international journal on mathematics education in Indonesia, established in 2010 by Sriwijaya University (Indonesia) in collaboration with the Indonesian Mathematical Society (IndoMS), a joint initiative of the Netherlands and Indonesia to popularize the RME (Zulkardi et al., 2019). It is the first international journal in the field of mathematics education in Indonesia to be indexed in Scopus in 2018 (Zulkardi & Prahmana, 2021). A large number of research papers on RME were published in JME journals during the two stages of development of RME theory. Statistics on the number of publications, organizations, and sources of RME studies also reaffirm Indonesia's position in research and educational development strategies associated with the country's RME theory. Additionally, ESM (Educational Studies in Mathematics) is a journal whose founding editor, Hans Freudenthal—the founder of RME theory—and a collaborating editor, Michèle Artigue, are among the top three authors with the most cited RME documents according to the Scopus database for the period 1972–2024 (Table 3).

This result not only reflects the importance of the pioneering research on RME but also highlights the global spread and influence of this theory on mathematics education, with these studies having a profound impact on both theory and practice, from teacher training to the development of mathematics curricula in many countries. Topics widely covered in these

studies include RME principles in teaching (using context and models); design-based research (teaching processes, teaching guides, etc.); and the application of RME to develop students' competences and skills.

One of the clear clusters in the research on RME is the application of RME theory in teaching, especially the development of students' problem-solving competence. Keywords such as problem solving and mathematical models clearly show the link between RME and students' solutions to situations in contexts meaningful to learners and aligned with their experiences.

The keywords related to PMRI that stand out are Design research and Learning environment, indicating that PMRI pays special attention to the learning environment and research design to create learning situations that are suitable for Indonesian students, i.e., considering the educational and cultural contexts of each country. Besides, one of the important keywords associated with PMRI is Ethnomathematics, or Ethno-Realistic Mathematics Education (Prahmana, 2022). This is a distinctive element of PMRI: the adaptation of RME theory to Indonesia's cultural and educational context, helping students see the connection between mathematics and the country's cultural and traditional elements.

It can be seen that an educational theory is studied in three aspects: the research and development of educational programs, knowledge fostering, and teacher training and implementation at all levels (Nguyen et al., 2020). There have been various studies on teacher training and education to implement the RME program. RME is studied with teachers from two perspectives, pre-service and in-service mathematics teachers (Ekawati & Kohar, 2016; Nguyen, 2005; Reinke & Casto, 2022; Rianasari & Guzon, 2024; Serbin et al., 2024; Taconis et al., 2016; Wubbels et al., 1997; Yilmaz, 2019).

RME is used in teaching geometry and algebra mainly at the elementary and middle school levels (Rusdi et al., 2020; Saleh et al., 2017; Syafriafdi et al., 2019). Studies on the application of RME in middle and high school teaching have been conducted (Loc & Hao, 2016; Loc & Tien, 2020; Muttaqin et al., 2017; Nuraida & Putri, 2020; Stephan & Akyuz, 2012). Several studies applying the guided reinvention perspective of RME theory at the undergraduate level have been conducted by various authors, including in abstract algebra (Larsen, 2013; Larsen & Lockwood, 2013; Larsen & Zandieh, 2007), differential equations (Marrongelle, 2007; Rasmussen & King, 2000; Rasmussen et al., 2006), and linear algebra (Wawro et al., 2012). The dominance of RME research at the primary and lower secondary levels can be traced back to the role and success of the Dutch Wiskobas project at the primary level (Treffers, 1993), several projects at the Indonesian primary and secondary levels (Do - PMRI, CoMTI, SEA-RME, ...), and the characteristics of this age group for access to "authenticity". In addition, keywords such as ICT, mathematics curriculum, and learning environment have become more prominent in recent studies, reflecting the integration of technology and curriculum reform in mathematics education, especially in the era of booming digital transformation. In this direction, the use of digital tools, such as m-learning, offers many advantages for designing effective learning experiences in the context of authentication (Fesakis et al., 2018), as well as for employing ICT

to organize the learning of geometric shapes using the foundations of RME theory (Zaranis, 2018).

This result demonstrates the robust development of RME theory, particularly at the elementary and lower secondary levels, while also opening up the potential for broader application at higher educational levels through the integration of technology and curriculum reform. This aligns with the characteristics of students at these educational stages, in which mathematical knowledge is best developed through real-life situations, enabling students to gain a deeper understanding of mathematical concepts. Additionally, applying RME theory at the university level can be highly effective for subjects such as abstract algebra and differential equations. The use of digital tools, such as mobile learning (m-learning), highlights technology's potential to design effective learning experiences that not only help students acquire knowledge but also foster problem-solving skills in real-world contexts. This becomes increasingly important, as technology can support students' learning in mathematics through digital geometry or simulation exercises grounded in RME theory.

Evolutionary Trajectories of RME

This analysis goes beyond quantifying outputs to illuminate the evolutionary trajectory of RME. RME has shifted from Freudenthal's philosophical, practice-oriented program (mathematics as human activity, didactical phenomenology) (Freudenthal, 1973; Freudenthal, 1991) to a vigorous instructional design theory developed by Gravemeijer (Gravemeijer, 1994; Gravemeijer & Cobb, 2006). The core concepts of RME are "guided reinvention", "progressive mathematization", "didactical phenomenology" and "self-developed models" supplemented by structural and pedagogical details, encompassing curriculum frameworks, model use, and assessment strategies (Van den Heuvel-Panhuizen, 1996; Cooper, 1998; Van Den Heuvel-Panhuizen, 2003; Rasmussen & Blumenfeld, 2007; Larsen & Zandieh, 2007; Larsen, 2013; Larsen & Lockwood, 2013; Davis, 2017; Laurens et al., 2017; Muttaqin et al., 2017; Loc & Tien, 2020; Mardiana et al., 2020; Winarti et al., 2012). Over the last two decades, RME has continued to be refined through design research, international adaptations, and the integration of digital modeling (Muttaqin et al., 2017; Fesakis et al., 2018; Gravemeijer, 2020). Simultaneously, ongoing theoretical debates - related to the concept of "reality," the issue of transferability, and the balance between skill and knowledge - have led to conceptual clarifications rather than a complete rejection of the approach (Rasmussen & King, 2000; Cooper & Harries, 2002; Sawatzki, 2016; Prahmana, 2022).

A significant recent theoretical extension is the integration of RME with digital learning environments (Septiany et al., 2015; Drijvers, 2019; Webb & Peck, 2020; Sipayung et al., 2021). The concept of "guided reinvention" is being reinterpreted by dynamic geometry software. In these settings, computers offer instant feedback, acting as a "virtual guide," enabling students to test hypotheses and redefine rules more quickly than with traditional pen-and-paper methods (Septiany et al., 2015; Drijvers, 2019). This signals a new phase of RME in which

"reality" is increasingly virtual yet still preserves "experiential reality" for a generation of digital-native students.

Geographically, the shift from its Dutch origins to its strong popularity in Indonesia and the United States, along with emerging participation from Vietnam and Turkey, reflects a transition from theory - building to practical application in diverse cultural contexts (Ekawati & Kohar, 2016; Muttaqin et al., 2017; Fauzana et al., 2020; Prahmana, 2022; Zulkardi & Prahmana, 2021; Kindangen et al, 2021; Rasmussen & Blumenfeld, 2007; Larsen, 2013; Larsen & Lockwood, 2013; Laurens et al., 2017; Nguyen, 2005; Loc & Hao, 2016; Loc & Tien, 2020; Nguyen et al., 2019; Prahmana et al., 2020; Yilmaz, 2019). The research topics have also shifted from fundamental "contextual problems" to current issues concerning "learning trajectories" and competency-based assessment (OECD, 1999; Gravemeijer & Doorman, 1999; Nuraida & Amam, 2019; Kindangen et al., 2021; Palinussa et al., 2021; Rianasari & Guzon, 2024). These findings provide empirical evidence that RME has moved beyond its ontological origins to become a strategic framework connecting constructivist theory with 21st-century curriculum reform.

CONCLUSION

This study has expanded the existing body of knowledge by providing a detailed bibliometric analysis of research on Realistic Mathematics Education (RME), going beyond previous studies. By analyzing 331 Scopus-indexed documents published between 1972 and 2024, this research delineates the evolution, thematic orientations, and collaborative networks within the RME domain. The findings show a significant rise in scholarly interest in RME, especially since 2018, aligning with global educational reforms and the need for innovative teaching methods in mathematics education. Notably, the Netherlands, the United States, and Indonesia emerged as central contributors, with Indonesia exhibiting marked growth in output due to national educational policies that prioritize contextual and practical mathematics learning. This research also indicates significant development of RME theory worldwide, particularly at the elementary and lower secondary school levels, with growing applications at higher educational levels, largely due to the integration of technology and curriculum reform. This expansion signifies the growing relevance of RME in enhancing teacher education, fostering students' problem-solving competencies, and integrating digital technologies into mathematics curricula, especially at the elementary and lower secondary levels, with emerging extensions into higher education contexts.

Limitations

Despite the valuable insights yielded by this bibliometric analysis, several limitations constrain the generalizability and comprehensiveness of the findings. To improve the accuracy and depth of future research on RME, a more comprehensive methodological approach is recommended. Specifically, subsequent studies should incorporate systematic reviews and mixed-method analyses that combine quantitative citation metrics with qualitative content evaluations to discern the nature and significance of influence within the field. Expanding the scope to include

various publication types — such as monographs, conference proceedings, and regional studies not covered by major databases — would provide a more inclusive and contextually grounded understanding of RME's global dissemination and theoretical development. Furthermore, analyzing citation contexts through qualitative coding would provide nuanced insights into how specific studies shape, challenge, or refine the theoretical and practical applications of RME. By addressing these gaps, future research can contribute to a more holistic and critically informed narrative of RME's trajectory and its transformative potential in mathematics education worldwide.

Conflict of Interest

The authors declare that they have no conflicts of interest in this research.

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APPENDICES

Table 2.

Citation – Country – Minimum number of documents per country: 3 – 18 clusters; 4 – 11 clusters; 2 – 25 clusters

No.	Country	Research publication	Quotation	No.	Country	Research publication	Quotation
1	Indonesia	160	1387	11	Denmark	4	230
2	United States	52	1172	12	Norway	4	57
3	Netherlands	35	1074	13	Malaysia	4	13
4	Turkey	16	177	14	Belgium	3	150
5	United Kingdom	11	155	15	South Korea	3	156
6	Australia	11	156	16	Germany	3	105
7	Vietnam	9	41	17	Sweden	3	32
8	South Africa	9	39	18	Spain	3	24
9	Greece	7	125	19	Taiwan	3	41
10	Thailand	5	71	20	Ireland	2	66

Table 3.

List of 24 authors with the highest number of citations on the topic of RME in the Scopus database from 1972 to 2024.

Rank	Author	Workplace	Nationality	LC	SC	PY
1	Van den heuvel-panhuizen m.	Freudenthal Institute	Netherlands	251	1721	1994
2	Gravemeijer k.	Freudenthal Institute	Netherlands	245	2783	1999
2	Doorman m.	Freudenthal Institute	Netherlands	245	1450	1996
3	Artigue m.	University of Paris Diderot-Paris 7	France	181	900	2013
3	Blomhøj m.	Roskilde University	Denmark	181	636	2013
4	Reusser k.	University of Zurich	Switzerland	126	1434	1997
4	Stebler r.	University of Zurich	Switzerland	126	264	1997
5	Laurens t.	University of Pattimura Ambon	Indonesia	119	124	2018
5	Batlolona f.a.	University of Pattimura Ambon	Indonesia	119	120	2018
5	Batlolona J.R.	State University of Malang	Indonesia	119	346	2018
5	Leasa m.	University of Pattimura Ambon	Indonesia	119	244	2018
6	Rasmussen c.	San Diego State University	United States	112	2342	2000
6	Kwon o.n.	Seoul National University	South Korea	112	500	2006
7	Verschaffel l.	University of Leuven	Belgium	80	9290	1997
7	Cutting and.	University of Leuven	Belgium	80	2566	1997
7	Zandieh m.	Arizona State University	United States	80	649	2008
8	Stephan m.	University of North Carolina Charlotte	United States	77	673	2012

8	Akyuz d.	Middle East Technical University	Turkey	77	312	2012
9	Sembiring r.k	Bandung	Indonesia	75	110	2008
9	Come on, S.	Lambung Mangkurat University	Indonesia	75	222	2008
9	Dagger m.	Utrecht University	Netherlands	75	180	2008
10	Papadakis s.	University of Crete	Greece	73	4869	2017
10	Kalogiannakis m.	University of Crete	Greece	73	3545	2017
10	Zaranis n.	University of Crete	Greece	73	1076	2016

Note: LC: Location Citation, SC: Scopus Citation

Table 4*.*

Top cited documents on higher education for sustainable development by Scopus citations, 1972–2024 (n = 331).

Rank	Title	Author (Year)	Source	LC	GC
1	The didactical use of models in realistic mathematics education: An example from a longitudinal trajectory on percentage	Van den heuvel-panhuizen m. (2003)	Educational Studies in Mathematics	251	1086
2	Context Problems in Realistic Mathematics Education: A Calculus Course as an Example	Gravemeijer k.; Doorman m. (1999)	Educational Studies in Mathematics	245	990
3	Conceptualizing inquiry-based education in mathematics	Artigue m.; Blomhøj m. (2013)	ZDM - International Journal on Mathematics Education	181	682
4	Every word problem has a solution - The social rationality of mathematical modeling in schools	Reusser k.; Stebler r. (1997)	Learning and Instruction	126	436
5	How does realistic mathematics education (RME) improve students' mathematics cognitive achievement?	Laurens t.; Batlolona f.a.; Batlolona j.r.; Leasa m. (2018)	Eurasia Journal of Mathematics, Science and Technology Education	119	532
6	An inquiry-oriented approach to undergraduate mathematics	Rasmussen v.; Kwon o.n. (2007)	Journal of Mathematical Behavior	112	296
7	Teaching Realistic Mathematical Modeling in the Elementary School: A Teaching Experiment with Fifth Graders	Verschaffel l.; De corte e. (1997)	Journal for Research in Mathematics Education	80	400
7	Defining as a mathematical activity: A framework for characterizing progress from	Zandieh m.; Rasmussen c. (2010)	Journal of Mathematical Behavior	80	219

	informal to more formal ways of reasoning				
8	A Proposed Instructional Theory for Integer Addition and Subtraction	Stephan m.; Akyuz d. (2012)	Journal for Research in Mathematics Education	77	206
9	Reforming mathematics learning in Indonesian classrooms through RME	Sembiring R.K.; Hadi s.; Duncan, M. (2008).	ZDM – International Journal on Mathematics Education	75	276
10	Improving Mathematics Teaching in Kindergarten with Realistic Mathematical Education	Papadakis s.; Kalogiannakis m.; Zaranis n. (2017)	Early Childhood Education Journal	73	190

Notes: PY: Year of publication, LC: Citation in analytical data, GC: Citation on Google Scholar

Table 5.

Top 10 Organizations with the Most Publications

No.	Organization	Country	Documents	Citations
1	Sriwijaya University	Indonesia	59	489
2	Utrecht University	Netherlands	34	1064
3	Ahmad Dahlan University	Indonesia	25	292
4	University Education	Indonesia	12	60
5	San Diego State University	United States	10	476
6	Portland State University	United States	10	412
7	Negeri Padang University	Indonesia	9	53
8	Arizona State University	United States	6	187
9	University of Semarang	Indonesia	6	41
10	Middle East Technical University	Turkey	6	41

Table 6.

The most influential publishers on the topic of RME from 1972 to 2024.

No.	Source	Publisher	TC	For example	SJR 2024
1.	Journal on mathematics education (JME)	Sriwijaya University	700	65	0.348
2.	Mathematics education journal (MEJ)	Sriwijaya University	22	21	0.188
3.	Journal of mathematical behavior (JMB)	Elsevier Inc.	592	20	1.235
4.	International journal of scientific and technology research (IJSTR)	India (2019)	48	20	0.12
5.	Mathematics teaching-research journal (MT-RJ)	City University off New York	48	17	0.301
6.	Educational studies in mathematics (ESM)	Springer Netherlands	832	15	1.589
7.	Infinity journal	STKIP Siliwangi Bandung	65	13	0.238
8.	ZDM-International journal on mathematics education (ZDM)	Springer Verlag (Germany)	501	11	1.534
9.	International journal of mathematics education in science and technology (IJEMST)	Turkey (2022)	131	10	0.433
10.	International journal of science and mathematics education (IJSME)	Springer Netherlands	72	8	1.108
11.	Mathematics education research journal (MERJ)	Springer Netherlands	133	7	1.244
12.	Journal for research in mathematics education (JRME)	National Council of Teachers of Mathematics	272	6	1.753
13.	European journal of educational research (EU-JER)	Eurasian Society of Educational Resesrch	38	6	0.369

Note: TC: Number of citations according to Scopus database; NP: Number of announcements; SJR: data from scimagojr.com.

Table 7.

Top 12 Keywords with the Highest Occurrences

No	Keyword	Occ	TLS	No	Keyword	Occ	TLS
1	RME	146	169	7	Mathematical models	13	21
2	Design research	45	51	8	Reinvention	12	19
3	PMRI	42	37	9	Mathematics	11	14
4	Mathematics education	32	79	10	Fraction	10	18
4	Problem solving	23	39	10	Context	10	12
5	Learning trajectories	19	35	11	Algebra	9	28
6	Students	15	65	12	Mathematization	9	11

Note TLS: Total link strength, Occ: Occurrences.