Thematic bibliometric analysis of 37 specialized journals in mathematical education research indexed in Scopus or Web of Science

Jorge Gaona 1*, Fabiola Arévalo-Meneses 2

1 Departamento de Pedagogía, Universidad de Playa Ancha, Valparaíso, CHILE
2 Instituto de Matemáticas, Pontificia Universidad Católica de Valparaíso, Valparaíso, CHILE

Received 01 February 2024 • Accepted 15 April 2024

Abstract
This bibliometric study examines the scientific production in mathematical education of 23,094 articles from 37 specialized mathematical education journals, indexed in Scopus and Web of Science, considering all records up to the year 2022. The analysis was conducted globally and regionally, including Latin America, Africa, Europe, the United States, and Canada. Articles were analyzed using rhizomatic conceptual spaces, which allow the representation of relationships between words present in the titles and keywords of articles through graphs, thereby identifying thematic nodes and connections, as well as visible and invisible peripheral elements. The results reveal the diversity of terms used in the field and the difficulties in capturing a disciplinary field using certain keywords. Common thematic nodes such as teaching, learning, knowledge, problem-solving, curriculum, assessment, and technology were observed, as well as regional differences in focus areas and theoretical currents. The study also highlights underexplored areas and suggests possible future research paths, including expanding searches in specialized sources, bibliometric analysis of specific topics, and temporal comparison of trends in the field.

Keywords: scientometrics, research networks, mathematical education, Scopus, WoS

INTRODUCTION
In recent years, numerous bibliometric studies have been carried out on scientific production in the field of mathematics education, exhibiting variability in the number of articles analyzed, the databases, and the methodologies employed. By conducting a search using the terms: keywords, co-word*, co-words, bibliometr*, scientometr*, scopus, impact factor*, wos, web of science”, systematic review”, journal index”, in conjunction with educat*, and math*, a result of just over 90 research articles between 2005 and 2023 is obtained, with two-thirds of these corresponding to the last three years.

The majority of these analyses address specific topics within mathematics education, with a large number of articles focused on technology. The bibliographic analyses of Borba et al. (2016) and Hwang et al. (2023) examine research trends on the use of technology in mathematics education. The former studies scientific production in mathematics education in 2,433 articles from Web of Science (WoS), ERIC, and PsycInfo databases, while the latter analyzes scientific production in mathematics education in articles from 14 specialized journals in the area. There are other articles, generally not exceeding 50 analyzed, that deal with more specific technology topics, such as the use of mobile devices (Bano et al., 2018), tablets (Svela et al., 2019), computational thinking (Gokce & Guner, 2022; Subramaniam et al., 2022; Ye et al., 2023; Yohannes & Chen, 2021), augmented reality (Jabar et al., 2022), and artificial intelligence (AI) (Hwang & Tu, 2021).

There are other bibliometric studies focusing on students or teachers, such as MacDonald and Murphy (2021), which is centered on the analysis of mathematics education articles related to children under four years old, or dos Santos de Oliveira Braga et al. (2022), who analyze academic production on youth and adult education, but only in Bolema [Bulletin] journal.

1 Symbol * is used in search engines if you want to search for any term that starts with a specific word.

© 2024 by the authors; licensee Modestum. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/).
*jorge.gaona@upla.cl (*Correspondence) fabiola.arevalo@pucv.cl
**Contribution to the literature**

- This research offers a methodological contribution to the systematic literature review, being replicable for future research, especially in the field of mathematics education by using graphs to study the co-occurrence of words.
- A comparative bibliometric analysis was carried out using a database of 37 specialized journals in mathematics education, which is the most extensive database analyzed to date. These specialized journals provide relevant information on the subjects of study and the topics addressed in different geographical regions, such as Latin America, Africa, the United States and Canada, and Europe.
- The study highlights the importance of keywords in research articles and the possibility of developing strategies to systematize the selection process in order to increase the visibility of published research.

Regarding teachers, there are different bibliographic reviews. Mills et al. (2020) conducted a systematic literature review about expert disciplinary teachers in primary science and mathematics education. Shamim et al. (2022) analyze articles on the pedagogical beliefs of technical education teachers in science, technology, engineering, and mathematics (STEM). Linder and Simpson (2018) focus on the analysis of early childhood mathematics education and its empirical research, concentrating on the practice of teachers and teachers in training. Stahnke et al. (2016) carry out a systematic review of empirical research on mathematics teachers’ situational skills, including perception, interpretation, and decision-making. With the exception of Linder and Simpson (2018), which analyzes around 1,200 articles, the rest of the reviews cover from a dozen to a hundred analyzed articles.

Additionally, there are bibliometric analyses focused on specific topics in mathematics education, such as instrumental approach (Drijvers et al., 2020), mathematical modeling (Hidayat et al., 2022), problem-solving (Suseelan et al., 2022), realistic mathematics (Phan et al., 2022), and pedagogical content knowledge (Depaepe et al., 2013). These studies analyze a range of 60 to 300 articles, mainly from Scopus and WoS databases.

Furthermore, there is another group of articles focused on academic production in a specific area of research. The work of Castro et al. (2020) examines nearly 3,500 open-access articles produced in Colombia from various sources, such as conference proceedings, theses, articles in national and international journals on mathematics education, among others. Meanwhile, Bracho-López et al. (2012, 2014) conduct an analysis of Spanish scientific production, analyzing 774 and 959 articles in Spanish journals specializing in mathematics education. Other analyzed locations include Turkey, with the works of Dede and Ozdemir (2022), who analyzed 441 articles in WoS, and Kaya (2022), who analyzed 904 articles in the field from the TR database in the same country. Finally, within this subgroup is the work of Torres-Alfonso et al. (2014), who analyzed 1,357 articles registered in ALME (Acta Latinoamericana de Matemática Educativa [Latin American Educational Mathematics Act]) during the period from 2000 to 2009.

In relation to global analyses, only three were found: the first by Gokce and Guner (2021), who analyzed 1,021 articles from WoS database from 1980 to 2019; with almost five times more articles (5,633 to be precise). Ramirez and Devesa (2019) examined articles indexed in Scopus from 1978 to 2017 in the area. Julius et al. (2021) carried out the analysis using the largest number of articles in mathematics education, examining the production in Scopus between 1980 and 2020, which involved the analysis of 12,670 articles. In the last three mentioned works, as well as in several of the analyses that included a significant number of articles, VOSviewer tool was used (van Eck & Waltman, 2010), which allowed obtaining information about productivity, impact, and thematic axes in academic production.

In summary, it is observed that there are few reviews focused on broader regions and that, moreover, although the last-mentioned articles carry out a review of a large number of articles, they do not consider the majority of specialized journals in the subject. In addition, they present a significant discrepancy in the number of articles analyzed. Based on these antecedents, we pose the following research questions:

1. What are the relevant topics produced in specialized mathematics education journals in Scopus and WoS?
2. What is the citation impact of articles by region?
3. What are the relevant topics in scientific production in mathematics education according to geographical region? In particular, in Latin America, Africa, the United States along with Canada, and Europe.

**CONCEPTUAL & METHODOLOGICAL FRAMEWORK**

In our study, we address knowledge from a rhizomatic perspective (Deleuze & Guattari, 1980). According to this approach, knowledge is heterogeneous and connects with other knowledge in a horizontal and fluid way. To map this knowledge, a
rhizomatic graph can be employed in which words are nodes and the co-occurrence between words defines the relationships between nodes. The rhizomatic approach to knowledge can be useful for obtaining a global view of scientific production. Furthermore, it allows, among other operations, to perform a significant rupture, that is, to prune nodes, without the rhizome completely disappearing, but transforming and allowing new interpretations.

Building on the work of Gaona and Manríquez (2023), the conceptual rhizomatic space (CRS) is developed by creating graphs that connect the words of an article (Figure 1). Using the algorithm defined in the aforementioned article, a quantitative measure of the frequency of words and relationships can be obtained.

To interpret this CRS, one must not only consider an isolated word and its repetition but also the relationship between words and the differences that occur Deleuze (2002). From this perspective, we are interested in examining, through word frequency, the relevant topics of scientific production in mathematics education, both globally and in some regions of the world, without focusing on other metrics such as the number of published articles or citations received, which, although useful for certain analyses, do not reflect the accumulated knowledge of a community of researchers in indexed journals, which currently function as philosophical stones of scientific production Andrade-Molina et al. (2020).

The regional approach will allow us to identify the emphases that each community, sharing a common and close geographical space, has, although like any list, this can be questioned (Eco & Bouzaher, 2009). To this end, four regions were chosen, and a certain number of countries were selected in each region, according to the following list:

1. **Latin America:** Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Panama, Peru, Puerto Rico, Uruguay, and Venezuela.


3. **North America:** The United States and Canada.

4. **Europe:** Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and Vatican City.

*Preferred reporting items for systematic reviews and meta-analyses* or PRISMA methodology was used (Yepes-Nuñez et al., 2021). The methodological decisions employed in this work are described below.

**Eligibility Criteria**

Delimiting a disciplinary field is not an easy task. In the review carried out, the articles that were analyzed conducted a search based on some keywords related to education and others related to mathematics, which, based on the work of Castro and Gómez (2021), seems clearly insufficient. Instead, in this article, we chose articles from specialized journals indexed in *Scopus* or...
WoS, trying to conduct a search that accounts for the core of scientific production in mathematics education. To select the journals, three criteria were used:

1. Journals whose name contains the words or strings of characters: mathematic, matemática, and math, in education or developmental and educational psychology categories of Scopus.
2. Journals whose name contains the words or strings of characters: mathematic*, matemática*, and math*, in education & educational research, education, scientific disciplines, or education, special categories of WoS.
3. Specialized journals that do not contain the aforementioned words but are reported in articles dealing with the analysis of specialized journals Andrade-Molina et al. (2020) and in Nivens and Otten (2017), and are indexed in Scopus or WoS, such as Acta Scientiae [Journal of Science], PRIMUS, or LUMAT, among others.

Inclusion & Exclusion Criteria

The search was conducted considering only research articles (articles) and reviews (review). Only articles up to the year 2022 were considered. The search was conducted at the beginning of March 2023. This resulted in the list shown in Table 1.

Data Extraction Process

The data extraction process was carried out following the work of Gaona and Manríquez (2023). Keywords and title words were separated into individual words, and “stopwords” or stopwords, such as connectives, articles, prepositions, and others, were removed. Next, common word roots or lemmas were searched for. Subsequently, the lists of words were merged. Finally, repeated words were removed, i.e., if a word appears in both the title and keywords, it is counted as a single occurrence.

To carry out the first process, Python’s split method was used. For the second and third processes, natural language toolkit (NLTK) (https://www.nltk.org/) was employed. To remove words, the stop words method in English was used. To join words according to a common root, the lemmatize method was used, which seeks to preserve the meaning of words.

From this, a graph was defined for each article. Each word represents a node, which we call \( v_i \). Furthermore, two words, denoted by \( v_i \) and \( v_j \), being in the same article are related by an edge called \( e_{ij} \) (Figure 1).

If the database has \( n \) scientific articles and we denote each of them by \( P_1, P_2, ..., P_n \). Observe that each \( P_i \) corresponds to a list or set of words obtained from the titles and keywords. Thus, we can write \( V=(V_1, V_2, ..., V_n) \), where each \( V_i \) is a list of words corresponding to \( P_i \).

To identify the relationships between the words that are in each \( V_i \), we associate a complete graph to each \( P_i \), where the set of vertices is \( V_i \). We denote this complete graph by \( G_i \). In summary, we associate a complete graph to each scientific article whose vertices are the words found in the titles and keywords of the analyzed articles.

Once the previous assignment has been made for each \( P_i \), we define the graph \( G \) as the union of all graphs \( G_i \). The union of graphs corresponds to the union of nodes and edges. In other words, \( G=G_1+G_2+ \cdots +G_n \).

It is possible and recurrent that a word in \( V_i \) is also in \( V_j \) with \( i \neq j \), that is, a node of the graph \( G_i \) is also a node of the graph \( G_j \). Similarly, we could have two or more nodes repeated in two different graphs, implying that the edges connecting them are also repeated. We quantify these repetitions in weight functions for nodes and edges of the graph \( G \) weighted by the total number of analyzed articles: \( w_{node}(v) \) is the number of \( V_i \) to which \( v \) belongs and \( w_{edge}(e) \) is the number of \( G_i \) in which \( e \) belongs.

As a result, according to these elements, CRS is defined as the weighted graph \( G \). Since the goal is to visualize CRS within a screen or a sheet of paper, the number of nodes and edges is limited in such a way that the most relevant relationships can be observed. Therefore, we consider the parameters \( \eta \) and \( a \) for visualization, where \( \eta \) will be the parameter regulating the display of nodes and \( a \) the parameter regulating the display of edges. We denote by \( G_{\eta,a} \) the graph obtained from \( G \) according to the parameters \( \eta \) and \( a \). Formally: \( G_{\eta,a}=(V_{\eta,a}, E_{\eta,a}) \) is a graph such that \( V_{\eta,a}=[v \in V: w_{node}(v) \geq \eta] \) and \( E_{\eta,a}=[e \in E: w_{edge}(e) \geq a] \).

Based on this, CRS \( G_{\eta,a} \) is defined, which will be displayed in different figures. In \( G_{\eta,a} \), some nodes can be pruned arbitrarily to facilitate the visualization of the remaining nodes. When this occurs, the pruned nodes and the reason for such pruning will be indicated.

Within \( G_{\eta,a} \), the visible periphery of CRS is identified as those words or relationships that are on the edges, remaining on the fringes, disconnected, or weakly connected. Although in \( G \), by definition, all nodes are connected, they are not in \( G_{\eta,a} \), as what is seen is a part of the whole, leaving out weaker relationships and nodes. However, there is an invisible periphery corresponding to all nodes and relationships not shown.

The algorithm operationalizing all these concepts is detailed in Gaona and Manríquez (2023, p. 16).

For citation analysis, data from Scopus will be used since all the consulted journals are from Scopus, while not all are from WoS. Moreover, even for journals appearing in both databases, the number of citations is higher in Scopus than in WoS. To analyze the distribution of citations in scientific articles, five different geographical regions were used: Latin America, Africa, the United States, and Canada, Europe, as well as Global. It is worth noting that articles can be repeated in two different regions if the affiliations belong to two countries from different regions. The region called
Table 1. List of journals, number of articles analyzed, & years considered in indexing

<table>
<thead>
<tr>
<th>No</th>
<th>Journal [Abbreviation]</th>
<th>Country</th>
<th>Q-2021 Scopus</th>
<th>WoS</th>
<th>n</th>
<th>Y1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acta Scientiae</td>
<td>ACTA</td>
<td>Brazil</td>
<td>Q4</td>
<td>296</td>
<td>2018-2022</td>
</tr>
<tr>
<td>3</td>
<td>Annales Universitatis Paedagogicae Cracoviensis [Studia ad Didacticae Mathematicae Pertinentia</td>
<td>AUPC-SDMP</td>
<td>Poland</td>
<td>Q4</td>
<td>25</td>
<td>2019-2021</td>
</tr>
<tr>
<td>4</td>
<td>Avances de Investigación en Educación Matemática [Research Advances in Mathematics Education]</td>
<td>AIEM</td>
<td>Spain</td>
<td>Q4</td>
<td>59</td>
<td>2018-2022</td>
</tr>
<tr>
<td>5</td>
<td>Bolema: Mathematics Education Bulletin</td>
<td>BOLEMA</td>
<td>Brazil</td>
<td>Q3</td>
<td>740</td>
<td>2010-2022</td>
</tr>
<tr>
<td>6</td>
<td>British Journal for History of Mathematics</td>
<td>BJHM</td>
<td>UK</td>
<td>Q4</td>
<td>47</td>
<td>2019-2022</td>
</tr>
<tr>
<td>7</td>
<td>Canadian Journal of Science, Mathematics, &amp; Technology Education</td>
<td>CJSMET</td>
<td>Canada</td>
<td>Q2</td>
<td>694</td>
<td>2001-2022</td>
</tr>
<tr>
<td>8</td>
<td>Eduacacion Matematica</td>
<td>EM</td>
<td>Mexico</td>
<td>Q4</td>
<td>120</td>
<td>2018-2022</td>
</tr>
<tr>
<td>9</td>
<td>Educational Studies in Mathematics</td>
<td>ESM</td>
<td>Netherlands</td>
<td>Q1</td>
<td>2095</td>
<td>1968-2022</td>
</tr>
<tr>
<td>10</td>
<td>EURASIA Journal of Mathematics, Science, &amp; Technology Education</td>
<td>EJIMSTE</td>
<td>UK</td>
<td>Q1</td>
<td>2037</td>
<td>2006-2022</td>
</tr>
<tr>
<td>11</td>
<td>European Journal of Science and Mathematics Education</td>
<td>EJSMME</td>
<td>Cyprus</td>
<td>Q3</td>
<td>64</td>
<td>2020-2022</td>
</tr>
<tr>
<td>12</td>
<td>For Learning of Mathematics</td>
<td>FLM</td>
<td>Canada</td>
<td>Q3</td>
<td>159</td>
<td>2011-2022</td>
</tr>
<tr>
<td>14</td>
<td>International Journal of Innovation in Science &amp; Mathematics Education</td>
<td>IJISME</td>
<td>Australia</td>
<td>Q3</td>
<td>315</td>
<td>2010-2022</td>
</tr>
<tr>
<td>16</td>
<td>International Journal of Science &amp; Mathematics Education</td>
<td>IJSME</td>
<td>Netherlands</td>
<td>Q1</td>
<td>1278</td>
<td>2003-2022</td>
</tr>
<tr>
<td>17</td>
<td>International Journal of Science, Mathematics, &amp; Technology Learning</td>
<td>IJSMT</td>
<td>USA</td>
<td>Q4</td>
<td>146</td>
<td>2012-2022</td>
</tr>
<tr>
<td>18</td>
<td>Investigations in Mathematics Learning</td>
<td>IML</td>
<td>USA</td>
<td>Q3</td>
<td>196</td>
<td>2008-2022</td>
</tr>
<tr>
<td>19</td>
<td>Journal for Research in Mathematics Education</td>
<td>JRME</td>
<td>USA</td>
<td>Q1</td>
<td>409</td>
<td>1996-2020</td>
</tr>
<tr>
<td>21</td>
<td>Journal of Mathematical Behavior</td>
<td>JMB</td>
<td>USA</td>
<td>Q2</td>
<td>938</td>
<td>1994-2022</td>
</tr>
<tr>
<td>22</td>
<td>Journal of Mathematics Teacher Education</td>
<td>JMTE</td>
<td>Netherlands</td>
<td>Q1</td>
<td>466</td>
<td>2005-2022</td>
</tr>
<tr>
<td>23</td>
<td>Journal of Urban Mathematics Education</td>
<td>JUME</td>
<td>USA</td>
<td>Q4</td>
<td>17</td>
<td>2020-2022</td>
</tr>
<tr>
<td>24</td>
<td>Journal on Mathematics Education</td>
<td>JME</td>
<td>Indonesia</td>
<td>Q1</td>
<td>251</td>
<td>2010-2022</td>
</tr>
<tr>
<td>25</td>
<td>LUMAT</td>
<td>LUMAT</td>
<td>Finland</td>
<td>Q4</td>
<td>117</td>
<td>2016-2022</td>
</tr>
<tr>
<td>26</td>
<td>Mathematical Thinking &amp; Learning</td>
<td>MT &amp; L</td>
<td>USA</td>
<td>Q1</td>
<td>227</td>
<td>2009-2022</td>
</tr>
<tr>
<td>27</td>
<td>Mathematics Education Research Journal</td>
<td>MERJ</td>
<td>Netherlands</td>
<td>Q1</td>
<td>675</td>
<td>1989-2023</td>
</tr>
<tr>
<td>28</td>
<td>Mathematics Student</td>
<td>MS</td>
<td>India</td>
<td>Q4</td>
<td>112</td>
<td>2019-2022</td>
</tr>
<tr>
<td>29</td>
<td>Mathematics Teaching-Research Journal</td>
<td>MTRJ</td>
<td>USA</td>
<td>Q4</td>
<td>268</td>
<td>2006-2022</td>
</tr>
<tr>
<td>30</td>
<td>PRIMUS</td>
<td>PRIMUS</td>
<td>UK</td>
<td>Q3</td>
<td>1507</td>
<td>1991-2022</td>
</tr>
<tr>
<td>31</td>
<td>Research in Mathematics Education</td>
<td>RME</td>
<td>USA</td>
<td>Q3</td>
<td>436</td>
<td>2000-2022</td>
</tr>
<tr>
<td>33</td>
<td>School Science &amp; Mathematics</td>
<td>SSM</td>
<td>USA</td>
<td>Q4</td>
<td>139</td>
<td>1973-2022</td>
</tr>
<tr>
<td>34</td>
<td>Teaching Mathematics and its Applications</td>
<td>TMA</td>
<td>UK</td>
<td>Q2</td>
<td>1092</td>
<td>1982-2022</td>
</tr>
<tr>
<td>35</td>
<td>Teaching of Mathematics</td>
<td>TOM</td>
<td>Serbia</td>
<td>Q4</td>
<td>471</td>
<td>1998-2022</td>
</tr>
<tr>
<td>36</td>
<td>Turkish Journal of Computer &amp; Mathematics Education</td>
<td>TJMC</td>
<td>Türkiye</td>
<td>Q4</td>
<td>73</td>
<td>2014-2022</td>
</tr>
<tr>
<td>37</td>
<td>ZDM-International Journal on Mathematics Education</td>
<td>ZDM</td>
<td>Germany</td>
<td>Q1</td>
<td>1623</td>
<td>1997-2022</td>
</tr>
</tbody>
</table>

Note. UK: United Kingdom; USA: United States; Q: Quarter; n: Number of articles; Y1: Years indexed; & Total articles: 23,110

“Global” contains the previous regions and articles with affiliations from countries outside the analyzed regions.

The data were graphically represented using a boxplot, where the horizontal axis displays the regions, and the vertical axis shows the number of citations of the articles.

RESULTS

Global Analysis

Citation distribution by region

The distribution of citations across different geographical regions, as shown in Table 2 and Figure 2.
reveals a significant discrepancy in the number of citations between northern regions (Europe, the United States, and Canada) and southern regions (Latin America and Africa).

Latin America is the region with the lowest impact in terms of citations, both in quartile comparison and average.

A more in-depth analysis of the data indicates that there are a large number of uncited publications in all regions, which could be the result of various factors, such as lack of visibility, the quality of research, or the relevance of the studied subjects.

The absence of whiskers in the plot for Latin America, Europe, and the global set suggests that there is a wide range of publications that have not been cited, leading us to reflect on the reason for this low impact and for whom the writing is intended.

Additionally, it can be observed that the mean is located near the third quartile in all regions. This phenomenon is due to the presence of outliers, that is, those articles that receive an exceptionally high number of citations. These outliers “push” the mean upwards, which could give a distorted impression of the actual impact of publications in each region.

This discrepancy in the citation impact between the northern and southern regions could be the result of differences in resources and support for research, the quantity and quality of international collaborations, and access to publications. It could also be due to a concentration of research topics in areas that are more relevant or popular in the northern regions, resulting in a higher number of citations for those publications.

In summary, the citation distribution displays a clear disparity between geographical regions, and a more detailed analysis is needed to identify the underlying causes of these differences.

Moreover, it is essential to consider the role of outliers and their effect on the means, and to reflect on the possible reasons behind the high proportion of uncited publications in all regions.

Main topics of interest at global level

Regarding the thematic analysis, by calculating the \( G_{230,465} \) Global CRS or \( G_{230,465} \) complete ERC-Global based on the articles from the 37 analyzed mathematical education journals, the image shown in Figure 3 is obtained. Words were classified into five major groups: words associated with disciplinary content (mathematics and sciences), words associated with mathematical education, words associated with education in general, words associated with socio-cultural concepts, and a fifth category containing all words not included in previous categories.

Regional Analysis

Latin America

The principal journals in which articles affiliated with Latin America are published are presented in Table 3. It
Figure 3. G230,461 CRS weighted for 23,110 articles (color code: * Mathematical education concepts; * &  * Generic education concepts; * Concepts on social issues; Concepts not included in other categories; & for a more detailed view of G230,461, see https://datoseducativos.cl/rev_biblio_37_rev_ed_mat_hasta_2022/grafos_podado_GLOBAL_POND_title_key_metodo_met_lemmatize23094_n_23094_f_nodo_230_f_edge_461.html) (Source: Authors’ own elaboration)

Table 3. Top-5 journals featuring articles affiliated with Latin American countries (percentage is calculated on 100% corresponding to 1,530 articles affiliated with these countries)

<table>
<thead>
<tr>
<th>Journal</th>
<th>n</th>
<th>P (%)</th>
<th>AP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolema-Mathematics Education Bulletin</td>
<td>589</td>
<td>38.5</td>
<td>38.5</td>
</tr>
<tr>
<td>Acta Scientiae [Journal of Science]</td>
<td>205</td>
<td>13.4</td>
<td>51.9</td>
</tr>
<tr>
<td>International Journal of Mathematical Education in Science &amp; Technology</td>
<td>119</td>
<td>7.8</td>
<td>59.7</td>
</tr>
<tr>
<td>Educación Matemática [Mathematics Education]</td>
<td>93</td>
<td>6.1</td>
<td>72.4</td>
</tr>
</tbody>
</table>

Note. n: Number of articles; P: Percentage; & AP: Accumulated percentage

is important to highlight that nearly three-quarters of the articles are concentrated in these journals, four of which belong to the region.

On the other hand, Figure 4 shows the G15,30 ERC-Latin America. In this graph, it can be observed that the terms associated with teacher (27.8%) and teaching (21.6%) are more frequent than the terms associated with student (14.8%) and their learning (14.2%).

The terms linked to teaching mainly relate to words associated with the various stages of a teacher’s professional life, such as training (6.5%), development (6.5%), professional (4.8%), or preservice (2.8%). Similarly, there are terms connected with multiple words, both from the teaching and learning process, like knowledge (9.7%) or school (16.4%).

In the visible periphery of G15,30 ERC-Latin America, words related to cognitive processes can be seen, such as understanding (3.8%) or reasoning (3.0%). Regarding terms linked to mathematical education, the following pairs are observed: problem (6.9%) and solving (4.6%); technology (5.2%) and digital (3.5%). Additionally, there are isolated nodes like curriculum (4.4%), task (4.1%), textbook (4.0%), representation (3.9%), modeling (3.7%), modelling (3.7%), and assessment (2.7%), among others.

Also, words that are not present in the global scope but are in Latin American articles appear, such as apsos (2.5%), ethnomathematics (2.2%), onto-semiotic (2.2%), and socio-epistemology (1.1%). These words are related to specific theories of mathematics education of which ethno-mathematics and socio-epistemology are theoretical perspectives that were initially developed in Brazil and Mexico, respectively.

The main terms associated with mathematics or disciplinary are function (5.4%), geometry (4.0%), math (3.9%), algebra (3.7%), calculus (3.6%), statistic (3.5%), number (3.3%), science (3.2%), equation (3.0%), statistical (2.8%), engineering (2.7%), algebraic (2.5%), differential (2.5%), linear (2.2%), probability (2.2%), derivative (2.2%), and geometric (2.0%), among others.

In summary, the analysis of G15,30 ERC-Latin America provides an overview of the terms and concepts that prevail in mathematics education research in the Latin American region. It highlights the presence of terms related to teaching and learning, as well as specific
concepts of mathematics didactics and disciplinary terms.

Moreover, the influence of theories and perspectives inherent to the region, such as Ethnomathematics and Socio-epistemology, is observed. This analysis can be useful for identifying areas of research interest in mathematics education in Latin America and better understanding the region’s peculiarities compared to the global sphere.

Africa

In articles affiliated with African countries, a little over 40.0% of the articles are found in the *African Journal of Research in Mathematics, Science and Technology* from South Africa. The remaining 40.0% is distributed among four journals that are outside African Region (Table 4).

On the other hand, Figure 5 displays $G_{11,22}$ ERC-Africa. Here it can be seen that there are more studies focusing on teacher (27.6%) and teaching (18.3%) than on student (22.0%) and their learning (20.4%), learner (10.1%).

The nodes associated with teachers and teaching are linked with terms related to the stages of a teacher’s professional life (development [7.3%], practice [6.8%], pre-service [5.9%], professional [3.7%], and in-service [2.2%]).

Nodes associated with students and their learning are connected with terms related to educational levels such as school (16.0%), and high (2.9%), secondary (8.0%), university (4.9%), and primary (4.0%).

Additionally, there are several nodes connected to both teaching and learning, some of which are territorial terms from the continent like South Africa (south [11.4%]), African (7.0%), and Africa (6.3%), other nodes are related to topics inherent to mathematics education (knowledge [9.3%] or curriculum [7.2%]), disciplinary ones (science [17.1%] and physical [2.7%]), and about cognitive processes (understanding [7.2%]).

In the visible periphery, terms related to cognitive processes like thinking (2.9%) or reasoning (1.7%); mathematics education, such as the pair problem (5.6%) and solving (3.4%) or the unimodal islands assessment (3.2%), strategy (4.6%), technology (3.8%), perception (3.1%) and attitude (2.6%), among others.

**Mathematical or disciplinary** terms are seen as main nodes to some terms of basic sciences and school
curriculum terms such as more advanced topics in mathematics, such as, physics (4.5%), geometry (4.0%), equation (3.5%), chemistry (3.0%), number (2.6%), function (2.6%), biology (2.5%), engineering (2.2%), scientific (2.1%), linear (1.5%), calculus (1.4%) and algebra (1.3%), among others.

In addition, some social terms such as gender (2.3%), community (2.1%), identity (2.0%), policy (1.9%), and indigenous (1.8%), among others, are observed.

In summary, articles affiliated with African countries are concentrated in a few journals, primarily in African Journal of Research in Mathematics, Science and Technology. Studies in Africa focus more on teachers and teaching than on students and their learning. The terms associated with teaching are related to stages of a teacher’s professional life, whereas terms associated with learning are linked to educational levels. In addition, territorial, mathematics education-related, disciplinary, cognitive processes, and social terms are found in the ERC-Africa analysis.

The United States & Canada

In this region of the globe, 60.0% of the publications in the analyzed group of journals are produced in five journals of which the first three are from Europe, and the last two are from the United States and Canada, respectively (Table 5).

Upon calculating the G_{76,152} ERC-US-Canada, the Figure 6 is obtained. This reveals a slight predominance of articles related to student (19.6%) and learning (15.9%) over articles about teacher (18.9%) and their teaching (13.4%).

In the teaching pole, it is connected with stages of professional life of the teaching staff such as development (6.5%) and professional (3.9%); practice (6.0%) and preservice (4.4%), as well as with teaching levels, specifically elementary (6.3%) and secondary (3.6%), and in the disciplinary aspect with science (7.7%).

The student pole is connected with words associated with cognitive perspectives such as reasoning (5.6%) and understanding (5.3%), and with calculus (7.9%) in the disciplinary aspect.

Moreover, both teaching and learning are connected with school (school [7.4%] and high [2.5%]) and with knowledge (knowledge [6.8%]).

In the visible periphery of G_{76,152} ERC-USA-Canada, words associated with mathematical education are observed, such as the pair problem (7.5%) and solving.
Figure 6. Extract from $G_{76,152}$ pruned CRS for 7,619 articles affiliated with the United States & Canada (pruned words are education, mathematics, & mathematical; color coding: • Mathematical education concepts; • Disciplinary mathematical concepts; • & • Generic education concepts; • Concepts on social themes, & • Concepts not found in other categories; & for a more detailed view of $G_{76,152}$, see https://datoseducativos.cl/rev_biblio_37_rev_ed_mat_hasta_2022/grafos_podado_USA_CAN_POND_title_key_metodo_met_lemmatize7619_n_7619_f_nodo_76_f_edge_152.html) (Source: Authors' own elaboration)

Table 6. Top-5 journals featuring articles affiliated with European countries (percentage is calculated on 100% corresponding to 7,716 articles affiliated with these countries)

<table>
<thead>
<tr>
<th>Journal</th>
<th>n</th>
<th>P (%)</th>
<th>AP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Journal of Mathematical Education in Science &amp; Technology</td>
<td>1,740</td>
<td>22.6</td>
<td>22.6</td>
</tr>
<tr>
<td>Educational Studies in Mathematics</td>
<td>863</td>
<td>11.7</td>
<td>33.8</td>
</tr>
<tr>
<td>ZDM-Mathematics Education</td>
<td>852</td>
<td>11.1</td>
<td>44.9</td>
</tr>
<tr>
<td>Teaching Mathematics &amp; Its Applications</td>
<td>796</td>
<td>10.3</td>
<td>55.2</td>
</tr>
<tr>
<td>EURASIA Journal of Mathematics, Science, &amp; Technology Education</td>
<td>457</td>
<td>5.9</td>
<td>61.1</td>
</tr>
</tbody>
</table>

Note: n: Number of articles; P: Percentage; AP: Accumulated percentage

(4.0%), in addition to curriculum (5.0%), proof (4.1%), assessment (3.9%), technology (3.5%), modeling (3.0%), representation (2.9%), task (2.6%), discourse (2.2%), reform (2.2%), belief (2.2%), and STEM (2.2%), among others.

In the mathematical or disciplinary terms, there appear algebra (5.8%), function (4.2%), number (3.9%), equation (3.7%), geometry (3.3%), linear (2.7%), fraction (2.1%), differential (2.2%), statistic (1.9%), theorem (1.6%), and algebraic (1.4%), among others.

Also, more discreetly, some terms related to social themes appear such as social (1.8%), community (1.6%), identity (1.5%), and equity (1.2%).

In summary, the analysis of ERC-USA-Canada reveals a greater focus on issues related to students and learning, compared to teaching staff and teaching. An emphasis on cognitive aspects, different levels of teaching and specific disciplinary areas is also evident. Words related to mathematical education and mathematical topics occupy a prominent position, while terms linked to social issues appear more discreetly.

Europe

Similar to Latin America, the United States, and Canada, a little over 60.0% of the publications affiliated with European countries are found in five journals, four of which belong to the same region, as shown in Table 6.

Upon analyzing $G_{77,154}$ ERC-Europe, a slight predominance of themes related to student (15.4%) and their learning (12.2%) is observed, compared to themes about teacher (14.1%), and teaching (12.1%).

In relation to the teacher node, following the trend observed in other ERCs, the related nodes correspond to the stages of a teacher’s career (development [5.6%] and professional [3.1%]), in addition to knowledge (knowledge [6.0%]).

As for the student node, it is connected with the school and its levels: school (8.8%), secondary (4.3%), and primary (4.2%).

In the visible periphery of $G_{77,154}$ ERC-Europe, words associated with mathematical education are found, such as the pair problem (7.2%) and solving (3.9%); along with other terms, like modelling (3.9%), task (3.3%), assessment (3.2%), representation (2.6%), technology (2.6%), curriculum...
In associating the around specialized covered out showing mentioned. words learning frequency (1.2%), (2.8%), science belief (2.5%), 

Figure 7. Extract from G77,154 pruned CRS for 7,619 articles affiliated with the European (pruned words are education, mathematics, & mathematical; color coding: • Mathematical education concepts; • Disciplinary mathematical concepts; • & Generic education concepts; • Concepts on social themes, & Concepts not found in other categories; & for a more detailed view of G77,154, see https://datoseducativos.cl/rev_biblio_37_rev_ed_mat_hasta_2022/grafos_podadoEURPOND_title_key_metodo_met_lemmatize7708_n_7708_f_nodo_77_f_edge_154.html (Source: Authors’ own elaboration)

(2.5%), proof (2.5%), computer (2.5%), strategy (2.2%), and belief (1.9%), among others.

In terms of mathematical or disciplinary terms, science (4.9%), number (3.4%), geometry (3.0%), function (2.8%), algebra (2.5%), equation (2.2%), engineering (1.6%), linear (1.5%), arithmetic (1.5%), calculus (1.4%), statistic (1.4%), physics (1.4%), algebraic (1.3%), and differential (1.2%), among other terms, appear. Words with low frequency related to social aspects are observed (Figure 7).

CONCLUSIONS & DISCUSSION

In the introduction of this work, extensive literature on bibliographic reviews in mathematics education was mentioned. Globally, the study by Julius et al. (2021) stands out for having analyzed 12,670 articles. In contrast, this work reviewed more than 23,000 articles, showing a significant difference. It is important to point out that this discrepancy is not due to the two years not covered in the cited study, since in 2021 and 2022, the specialized journals examined in this work published around 3,000 articles. The disparity primarily lies in how the field of mathematics education is delimited in this and other bibliometric review works, which consists of associating the disciplinary field with a few keywords. In fact, according to Julius et al. (2021, p. 3), the search was based on the terms: TITLELEABS–KEY(mathematics AND (edu* OR teach* OR learn* OR train* OR pedagogy OR student* OR curricul*))}, meaning that only a minimum part of the words that encompass research in specialized journals were used, as observed in the different ERCs analyzed in this work.

To be more precise, when searching for the intersection of these words with the specialized journals of this article, just over 9,000 articles are obtained, that is, less than half. This situation not only occurs in global searches but also in searches for specific topics, as many articles are often excluded due to the limited use of keywords in the search.

Another interesting result is the asymmetry observed in the large number of articles of bibliographic reviews of technology, which in both the global and regional analysis, does not exceed 6.0%, in contrast to the few bibliographic reviews focused on the teacher or the student, which are the most recurring nodes in each of ERCs analyzed.

In relation to the global and regional ERCs, it was observed that, in addition to the student and the teacher, the topics on cognitive processes are the most frequent nodes. On the contrary, studies involving embodied, inactive, or emotional perspectives are part of the invisible periphery, that is, they appear well below 1.0%.

Although there are differences between regional emphases, this thematic difference seems much more attenuated than the difference in the impact of articles. Large number of uncited articles is also observed, which would require specific analysis, as they are invisible and this could be for a number of reasons, from how recent these could be, to the themes analyzed, among many other reasons. Writing an article seems to be throwing a bottle with a message into the sea that may reach
someone, however, it is observed that many of these messages do not reach anywhere, at least as far as Scopus metrics are concerned.

In terms of regional analysis, on one hand, there is some convergence on the big nodes: teachers and students. However, the emphases and denominations vary, especially in relation to the initial training of teachers. In the countries of the global south, there is an emphasis on studies focused on teachers, while in the countries of the north, there is a greater focus, although slight, on students. In addition, some words are observed in the visible periphery both in Latin America and in Africa that do not appear either in the global analysis or in the other regions. In the case of Latin America, we refer to words that refer to theoretical currents developed in the region, such as Ethnomathematics or Socio-epistemology, in addition to other theoretical currents that appear frequently. In the case of Africa, what is distinctive.

Like all studies, this one has its limitations. The most obvious limitation is that, although this review is larger than all those described in the problem, this work only considers specialized journals, leaving out all the mathematics education research present in related journals, such as Enseñanza de las Ciencias [Science Teaching], Computer Applications in Engineering Education or Computer & Education, among many others. Also left out are articles on mathematics education that appear in journals that are neither in the area nor related, but that accept articles related to the subject, for example, Estudios Pedagógicos [Pedagogical Studies] or Education Policy Analysis Archives, among many other journals. This is without considering that there are a series of specialized journals, related journals, and articles in the area outside Scopus and WoS, which were the search universes in this case.

This study, together with the limitations just stated, has theoretical implications when it comes to delimiting research in a field of study or a subfield. In our particular case in mathematics education. In the literature review, several articles are presented as a global review of the field, but only by a numerical comparison we see that they are far from being comprehensive reviews. We should question more deeply how we can find all the articles that correspond to mathematics education or another topic of interest.

Another theoretical implication of this work has to do with making an analysis using the multiple relationships offered by graph theory. Dichotomous classifications are difficult to sustain, except in very coarse analyses. On the other hand, the multiplicity of meanings that words can have shown the importance of metadata, particularly keywords. It also shows their limitations. For a more precise classification of articles, current systems have the ability to store words according to specific parts of a paper. For example, if an author could place keywords according to subject matter, theoretical aspects and methodological aspects, among others, the analysis of large numbers of articles would be more accurate. In practical terms, this forces us to change and combine techniques and perspectives to delimit the field, for example, complementing the search in specialized journals with word searches, by authors in the field and combining them with AI analysis techniques, to establish with some degree of certainty those articles that really belong to the field.

These complementary techniques, together with an analysis of the literature using graphs (among other possible techniques) open up a series of possibilities for systematic literature reviews. This work sought to give a glimpse of the field of mathematics education through the analysis of 37 specialized journals, however, in the near future we want to deepen and extend this search in at least two directions. The first is to try to extend this search to the entire field of mathematics education, considering the limitations mentioned above. The second is to try to extend and deepen the analysis of more thematic reviews, for example, analyzing the scientific production of the field in a particular region, such as Latin America, or of some subtopic of the area, such as technology, among many others.

**Author contributions:** Both authors have sufficiently contributed to the study and agreed with the results and conclusions.

**Funding:** This study was funded by the Fondecyt Initiation Project No 11230953 & the National Doctorate Scholarship No 21231462, both financed by the National Agency for Research and Development of Chile.

**Ethical statement:** The authors stated that the study did not require an ethics committee. The study did not involve human or animal research. Additionally, data that is available through public domains were used during the study.

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

**Data sharing statement:** All data from this study can be found in the following public repository: https://github.com/jorgegaonap/37_journal_math_education/blob/main/df_final.csv

**REFERENCES**


https://www.ejmste.com