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Unveiling Emerging Trends and Potential Research Themes in Future Ethnomathematics Studies: A Global Bibliometric Analysis (From Inception to 2024)

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Abstract. Ethnomathematics, an interdisciplinary field that bridges mathematics and culture, addresses the challenge of integrating cultural contexts into mathematics education. This study aimed to explore the global landscape, trends, and fundamental research themes in ethnomathematical studies while identifying areas for further development through a comprehensive bibliometric analysis. It addresses the current problem of integrating cultural contexts into mathematics education, filling research gaps by identifying emerging themes and trends. Using metadata from the Scopus database (1984–2024), 644 documents were collected with the search string "ethnomathematics". The study's investigative activities include research design, data collection, analysis, visualization, and interpretation. Data were processed using Biblioshiny R and VOSviewer to identify publication trends and to map keywords. The results indicated that authors such as Rosa and Orey are notable for their publication productivity, while Prahmana and D'Ambrosio are highly influential based on citation counts. The findings also showed a significant growth in ethnomathematical studies from 2010, peaking in 2020 and 2023. Keywords such as "students", "mathematics learning", and "Indonesia" frequently appeared, underscoring the focus on mathematics education linked to local cultural contexts. Future research directions include integrating technology in culture-based mathematics learning, developing numeracy and problem-solving skills through ethnomathematics, designing culture-based school curricula, evaluating ethnomathematics-based learning, and advancing teacher professional development in ethnomathematics instruction. These findings underscore the potential of ethnomathematics to enhance educational quality by making mathematics more relevant and engaging, ultimately contributing to a more inclusive and culturally responsive educational system.

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1. Introduction

Ethnomathematics offers a transformative perspective on mathematics education by integrating cultural contexts into mathematical learning. It is an interdisciplinary field that explores the relationship between mathematics and culture (D'Ambrosio, 2018; Thomas & Jacob, 2021). Ethnomathematics challenges the traditional view of mathematics as universal, recognizing it as a cultural construct that reflects diverse social practices (Rosa & Gavarrete, 2017). The primary aim of ethnomathematics is to recognize and value the connections between cultural practices and mathematical concepts (Rosa & Orey, 2011; Thomas & Jacob, 2021). This approach emerged in response to the common perception of mathematics as a purely abstract and complex subject, often viewed as separate from cultural contexts (Barton, 1996). By linking mathematics to students' cultural backgrounds, ethnomathematics makes learning more relevant and engaging (Rodríguez-Nieto & Alsina, 2022; Rosa & Orey, 2011).

Ethnomathematics has gained increasing attention in global academic discourse as a field that bridges mathematics and culture. The study of ethnomathematics has expanded rapidly, with numerous studies exploring its applications in multicultural education, local culture, and traditional games (Salsabilah et al., 2022; Serepinah & Nurhasanah, 2023; Tamur et al., 2023). Ethnomathematics examines how mathematical concepts are embedded in local cultural practices and offers more profound insights into the everyday applications of mathematics (Rodríguez-Nieto & Alsina, 2022). Ethnomathematics enhances students' engagement and understanding by making mathematics learning more meaningful and culturally relevant (Rodríguez-Nieto & Alsina, 2022). As an interdisciplinary field, it helps individuals comprehend how traditional cultural practices shape mathematical thinking (Bender & Beller, 2018).

The study of ethnomathematics has evolved in recent decades and covers a wide range of topics from introducing mathematical practices in cultural contexts to exploring diverse ways of thinking about mathematical concepts (Albanese et al., 2017). Research in ethnomathematics has increased, with several themes emerging including student learning approaches, the exploration of mathematical concepts, and the integration of ethnomathematics into formal education (Rusli & Safaah, 2023; Usman & Wijaya, 2024). The development of ethnomathematical studies focuses on discovering mathematical concepts within cultural contexts to improve the quality of mathematics education (Rosa et al., 2016). Furthermore, the integration of ethnomathematics into mathematics teaching such as geometry has been emphasized in several countries, including Indonesia, Zimbabwe, Nigeria, and Israel (Kyeremeh et al., 2023). Expansion of these themes in ethnomathematical studies may lead to challenges in determining the focus of future research. Therefore, further exploration is needed to identify new themes that can be developed in ethnomathematical studies.

Several studies have explored the field of ethnomathematics, including the development of web tools that enable students to create cultural art simulations such as Native American beadwork, African-American cornrow hairstyles, and urban graffiti, all of which are grounded in mathematical principles (Eglash et al., 2006). In Indonesia, ethnomathematics research has focused on historical buildings, traditional ceremonial equipment, games, and cake-making (Nisa & Hidayati, 2024; Pathuddin et al., 2021; Supriadi, 2022; Wiryanto et al., 2022). Review studies have also been conducted. For instance, Deda et al. (2024) performed a bibliometric analysis of research from 2012 to 2022 using the Google Scholar and Scopus databases and the PRISMA method to identify key authors and research themes in ethnomathematics. Kyeremeh et al. (2023) conducted a systematic review and bibliometric analysis of ethnomathematics in geometry education (2011–2021), identifying five main themes but offering limited details on methodology or future research directions. Sepúlveda-Herrera and Huincahue (2024) reviewed mathematical modeling in ethnomathematics, focusing on teacher education, but their study was confined to modeling aspects and did not explore global trends comprehensively. Meanwhile, Usman and Wijaya (2024) employed bibliometric analysis using the Scopus database up to February 2024 to reveal research trends, influential authors, and emerging themes in ethnomathematics, covering the period from 1984 to 2024.

Although several studies and bibliometric analyses have been conducted in ethnomathematical research, gaps still need to be addressed. Previous research has primarily focused on prolific authors or general themes without exploring potential keywords that are relevant to future research development. Some studies did not use metadata mapping software and others relied solely on Bibliometric R or VOSviewer. However, the combined use of both Bibliometric R and VOSviewer can provide a more comprehensive overview of the field. For instance, Kyeremeh et al. (2023) and Sepúlveda-Herrera and Huincahue (2024) did not employ metadata mapping software but instead, based their findings only on the information presented in the reviewed articles, which limited the identification of unexplored research areas. Deda et al. (2024) analyzed the research landscape from the past decade using VOSviewer. However, their study did not fully capture the broader publication landscape or reveal emerging research opportunities for future exploration.

Similarly, Usman and Wijaya (2024) used only Bibliometric R to identify general trends in ethnomathematics. However, they did not provide an in-depth analysis of the relationship between the identified keywords and the broader ethnomathematics keyword set. Furthermore, the rationale behind their keyword recommendations for future research—such as the number of occurrences of these keywords in conjunction with ethnomathematical terms—was not fully explained, making it unclear whether these keywords were novel or already established. Therefore, this study was conducted to complement existing bibliometric studies by introducing a novel approach combining Biblioshiny R and VOSviewer to provide a more comprehensive overview of ethnomathematical publications. The study aimed to offer a broader analysis of the landscape and publication trends in ethnomathematics, to uncover the main

themes in current research, and to identify the research gaps that require further exploration. To support these objectives, this study was guided by three key questions:

1. What are the overviews and global trends in ethnomathematics studies?
2. Which key research areas in ethnomathematics have been explored?
3. What are the potential themes for future research in ethnomathematics?

2. Methodology

This study employed a bibliometric analysis approach to examine a large dataset of ethnomathematical studies (Donthu et al., 2021). The study used the Scopus database, which was accessed on September 2, 2024. Scopus was chosen due to its ease of access and comprehensive metadata settings, making it a reliable source for research data. Additionally, Scopus is a reputable journal indexer that is widely used by researchers, and it offers a broad range of scientific literature (Baas et al., 2020; Gasparyan & Kitas, 2021).

This study carefully selected the appropriate keyword to ensure the availability of comprehensive metadata in ethnomathematical research. The keyword used was "ethnomathematic", which was chosen to encompass all fields of research or publications related to ethnomathematical studies. The investigation process included research design, data collection, data analysis, data visualization, and data interpretation, as shown in **Figure 1** (Salido, Sugiman et al., 2024; Zhu et al., 2023).

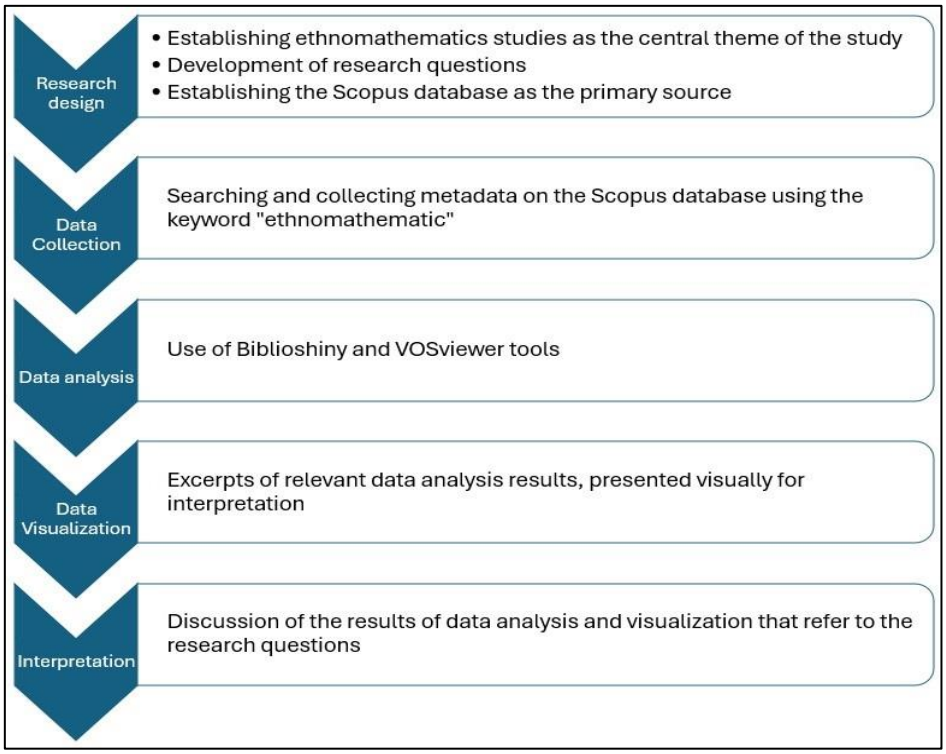

Figure 1: Steps of the study investigation

(Adapted from Zhu et al., 2023)

In the research design phase, key activities included establishing the ethnomathematics theme as the study's focus, formulating research questions to guide the reporting of results, and selecting the Scopus database as the primary source of research data. During data collection, 644 publication documents containing the predetermined keyword were retrieved from the Scopus database without any filtering process. All metadata were then exported in Comma Separated Value (CSV) format for further analysis.

The data analysis stage began after the data collection process was completed. This stage included analyzing the research landscape, identifying publication trends over time, and mapping keywords to provide a visual representation of ethnomathematical studies (Donthu et al., 2021). The data analysis was conducted using Biblioshiny R and VOSviewer; these were chosen for their ease of use and open-source availability (Salido, Sugiman et al., 2024). The initial phase of the data analysis employed Biblioshiny R to display the research landscape and publication trends, including the number of documents and citations for all publications, publication trends from the first year of inclusion in the Scopus database, influential authors, countries with the highest number of publications, and authors with the most citations. Subsequently, VOSviewer was used to visualize keyword correlations, helping to identify key issues in ethnomathematical studies and highlight future research opportunities.

The data visualization stage occurred alongside the data analysis where visual representations of the analysis results were generated. The visualizations that were relevant to the research were presented as the study's findings and then interpreted and discussed. In this case, data visualization and interpretation happened simultaneously. The data interpretation was conducted to address the study's research questions, including the analysis of publication trends, key research areas, influential authors and countries in ethnomathematics, and potential directions for future studies.

3. Results

This section discusses the key findings from the data analysis. Notable insights include an overview of global research trends, central themes in ethnomathematical studies, and potential themes for future studies.

3.1 Overviews of Global Trends in Ethnomathematics Studies

3.1.1 Productive Countries in Publications

The top-ten countries with the highest number of publications from 1984 to 2024 are shown in Table 1.

Table 1: Top-ten productive countries from 1984 to 2024

Country	Documents	Citations	Total link strength
Indonesia	272	1045	28
Brazil	118	539	35
United States	72	733	24
Spain	21	84	12
South Africa	18	149	10

Colombia	17	22	8
France	15	30	6
Malaysia	13	9	10
Australia	12	108	4
United Kingdom	10	125	4

Based on **Table 1**, according to the Scopus database, Indonesia is the most productive country in ethnomathematics studies with 272 published documents, 1,045 citations, and a collaboration network strength of 28. Brazil follows in second place with 118 papers and 539 citations and demonstrates the highest collaboration network strength of all the countries at 35. The United States ranks third with 72 papers but has a notably high citation count of 733 and a collaboration network strength of 24. Other countries such as Spain, South Africa, Colombia, France, Malaysia, Australia, and the United Kingdom have fewer documents but show active involvement in ethnomathematical research. For instance, South Africa has published 18 papers with 149 citations, reflecting significant influence despite its smaller output.

3.1.2 Productive Authors in Publications

The top-ten authors with the highest number of publications from 1984 to 2024 are shown in **Table 2.**

Table 2: Top-ten productive authors from 1984 to 2024

Author	Documents	Citations	Total link strength
Rosa, M.	23	127	36
Orey, D. C	18	127	27
D'ambrosio, U.	12	219	6
Knijik, G.	12	81	7
Zaenuri	12	36	26
Prahmana, R. C. I.	10	225	19
Oliveras, M. L.	10	45	15
Albanese, V.	9	32	9
Widada, W.	8	103	29
Herawaty, D.	8	97	30

Table 2 shows that Rosa is the most prolific author in ethnomathematics studies, with 23 publications, 127 citations, and a collaboration network strength of 36. Orey ranks second with 18 publications, 127 citations, and a collaboration network strength of 27. D'Ambrosio, Knijnik, and Zaenuri each have 12 publications although their citation counts differ. D'Ambrosio has the highest citation count, with 219 citations. Furthermore, Prahmana and Oliveras both have 10 publications, but Prahmana received the highest number of citations overall with 225 citations. Albanese has nine publications and has received 39 citations, while Widada and Herawaty have eight publications and 103 and 97 citations, respectively.

3.1.3 Influential Authors in Publications

The 10 authors with the highest number of citations from 1984 to 2024 are shown in **Table 3.** Based on **Table 3**, Prahmana has the highest number of citations, with

225 citations from 10 published documents, and a significant collaboration network strength of 19. D'Ambrosio, while having more publications than Prahmana, has fewer citations and a weaker collaboration network. Eglash, with only four publications, received 193 citations, demonstrating that despite fewer publications, his work has a substantial impact on ethnomathematics studies. Bennett, Cintorino, Jennings, and O'Donnell have published only one document each. However, each author has received 136 citations, indicating that their limited output has strongly influenced the academic community. Rosa and Orey are prolific authors, with 23 and 18 publications, respectively, but their citation counts, both at 127, suggest that despite their productivity, the overall impact of their work remains moderate. Ascher, with six publications and the same number of citations as Rosa and Orey, demonstrates a significant impact relative to his output.

Table 3: Top-ten influential authors from 1984 to 2024

Country	Documents	Citations	Total link strength
Prahmana, R. C. I.	10	225	19
D'ambrosio, U.	12	219	6
Eglash, R.	4	193	6
Bennet, A.	1	136	4
Cintorino, M.	1	136	4
Jennings, S.	1	136	4
O'Donnell, C.	1	136	4
Rosa, M.	23	127	36
Orey, D. C.	18	127	27
Ascher, M.	6	127	1

3.1.4 Publication Trends and Topics

Based on the Scopus database, ethnomathematics studies have been published since 1984. This finding aligns with the findings of Barton (1996), which revealed that ethnomathematics was first introduced in 1984 by D'Ambrosio at an International Congress of Mathematics Education. However, the development of ethnomathematics publications has fluctuated over time. In the early years, its presence was inconsistent. A complete analysis of global publication trends in ethnomathematics studies is presented in **Figure 2.**

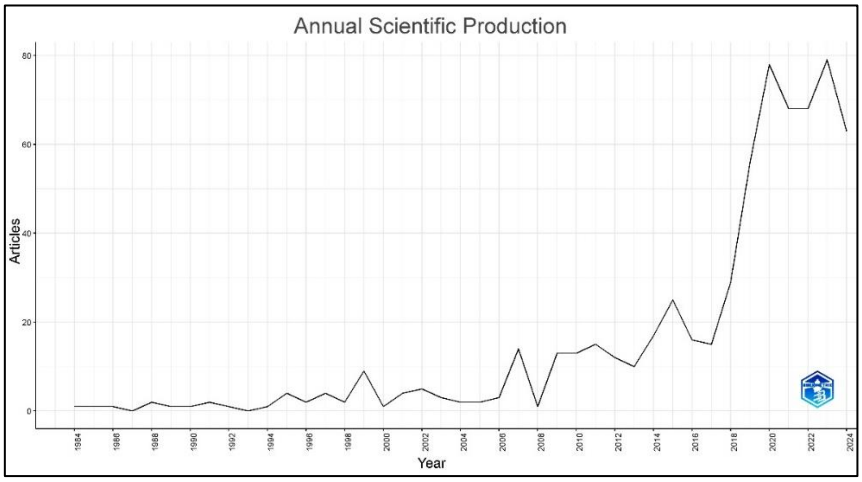

Figure 2: Annual scientific production

(Source: Author's elaboration using Biblioshiny R)

Based on **Figure 2,** publications on topics relating to ethnomathematics in Scopus-indexed journals experienced slow growth in the early years. From 1984 to 2010, the number of publications remained very low, with fewer than five articles published yearly. However, from 2010 to 2018, publications increased moderately, with a notable rise in 2015 when more than 20 articles were published. From 2018 to 2024, there was a significant surge in publications, with the highest numbers being recorded in 2020 and 2023, nearing 80 articles per year.

In addition to spanning a long publication period, ethnomathematics has developed a clear trend in study topics, reflecting shifts in research focus. **Figure 3** presents complete trending topics of ethnomathematics studies.

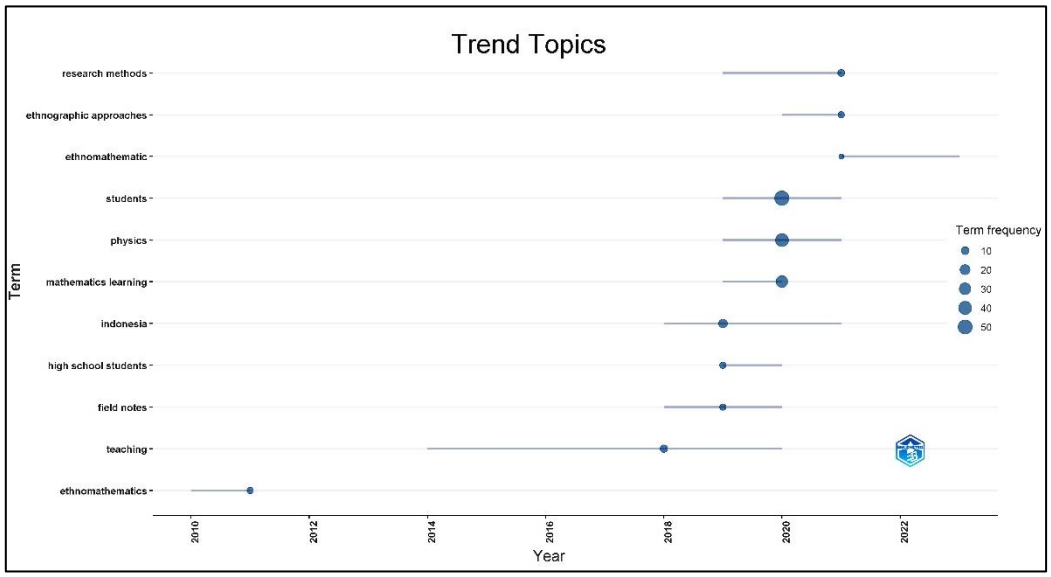

Figure 3: Trending topics of ethnomathematics studies

(Source: Author's elaboration using Biblioshiny R)

Figure 3 reveals that since 2010, common keywords in global ethnomathematics studies include "students", "physics", "mathematics learning", and "Indonesia". The term "students" appears most frequently, highlighting its prominence as a central focus in ethnomathematics research. "Physics" follows closely behind, ranking second in frequency and often appearing in article metadata. Additionally, "mathematics learning" and "Indonesia" emerge as critical topics, reflecting the attention given to mathematics education and specific research contexts in Indonesia. Furthermore, since 2014, several issues such as "teaching", "field notes", "Indonesia", "high school students", "research methods", "students", "physics", "mathematics learning", and "ethnographic approaches" have shown an upward trend in frequency, indicating increasing scholarly interest during this period.

3.2 Key Research Areas in Ethnomathematics

Various keywords have been explored since the early stages of ethnomathematical studies. Several keywords associated with ethnomathematical research over time are displayed in an overlay visualization overview in **Figure 4.** **Figure 4** illustrates that ethnomathematics has become a central topic in research and publications, as evidenced by the publication periodization. The color contrast in the VOSviewer visualization overlay highlights different publication periods in which yellow indicates the most recent publications and dark blue represents earlier works (Marín-Marín et al., 2021; Salido, Haryanto et al., 2024). Keywords in blue such as "philosophy", "cognition", "constructivism", "epistemology", and "pattern" refer to classical or foundational topics in ethnomathematics from earlier periods, focusing on theoretical and conceptual approaches. In contrast, the bright yellow keywords, including "personnel training", "culturally diverse classrooms", "educators", "conventional learning", "teachers' beliefs", and "numeracy skills" represent more recent publications with practical, application-oriented themes.

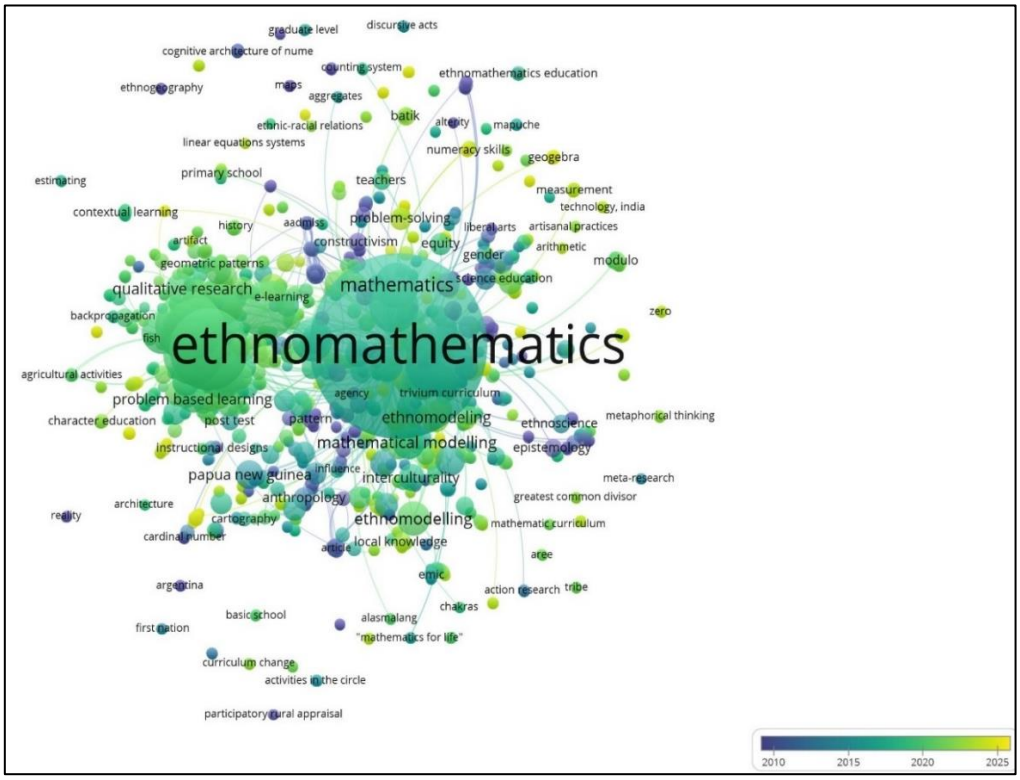

Figure 4: Key research areas in ethnomathematics
(Source: Author's elaboration using VOSviewer 1.6.20)

Additionally, **Figure 4** shows several recurring keywords such as "students", "mathematics", "mathematics education", and "physics", which are common themes in ethnomathematics studies. Specifically, **Figure 5** shows 10 frequently used keywords representing general research themes in ethnomathematics.

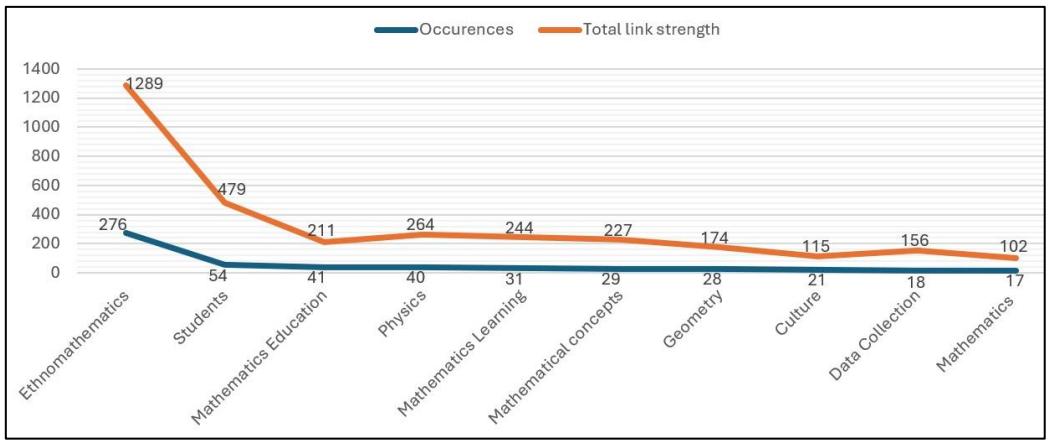

Figure 5: Top-ten keyword trends in ethnomathematical studies

Based on **Figure 5,** the keyword "ethnomathematics" had the highest occurrence, appearing 276 times and with a total link strength of 1,289. These findings indicate that ethnomathematics has become a central theme in numerous publications and is connected to other disciplines. The keywords "students", with 54 occurrences and a total link strength of 479, and "mathematics education", with 41 occurrences and a total link strength of 211, ranked second and third, respectively,

highlighting the significance of students and mathematics education as primary focuses in ethnomathematical research. The keyword "physics" is also prominent in this field, with 40 occurrences and a total link strength of 264, reflecting its relevance in conference proceedings that explore ethnomathematics. Other frequently occurring keywords in the top-ten trends include "mathematics learning" (31 occurrences, link strength 244), "mathematical concepts" (29 occurrences, link strength 227), "geometry" (28 occurrences, link strength 174), "culture" (21 occurrences, link strength 115), "data collection" (18 occurrences, link strength 156), and "mathematics" (17 occurrences, link strength 102). These keywords suggest a close relationship between ethnomathematics and these fields, with the high link strengths emphasizing the interdisciplinary nature of ethnomathematics and connecting it to educational practices and cultural studies. This finding aligns with the core objective of ethnomathematics, which is to integrate cultural contexts into mathematics learning.

3.3 Potential Themes for Future Research in Ethnomathematics

Several new keywords emerged in ethnomathematics studies during the 2020−2024 period, highlighting the potential for broader research themes. These keywords included "GeoGebra", "educators", "numeracy skills", "problem-solving", "primary school", "personnel training", "mathematical literacy", "numeracy", "measurement", "curriculum", "curriculum mathematics", "elementary levels", "elementary schools", "elementary school students", "elementary schools education", and "mathematics curriculum". These terms suggest new research opportunities that are focused on developing numeracy literacy and culture-based curricula, particularly at the primary education level. Additionally, integrating technology, such as the use of GeoGebra in culturally relevant mathematics learning, offers innovative ways to enhance interactive learning and address the needs of students in the digital age. Visually, these keywords are represented in **Figure 6**.

Based on **Figure 6**, several new keywords have emerged in ethnomathematical studies, suggesting a new direction for future research. The keyword "GeoGebra" is linked with "ethnomathematics," indicating efforts to integrate technology into culture-based mathematics learning. Additionally, the keyword "primary school" is connected with "ethnomathematics", reflecting the growing interest in applying ethnomathematical approaches at the elementary school level. Furthermore, the keywords "numeracy" and "problem-solving" each appear once with "ethnomathematics", highlighting recent research that explores how ethnomathematics can enhance numeracy and problem-solving skills. However, the keyword "mathematics curriculum", which does not link to the ethnomathematics theme, suggests a gap between the development of formal mathematics curricula and the concepts of ethnomathematics.

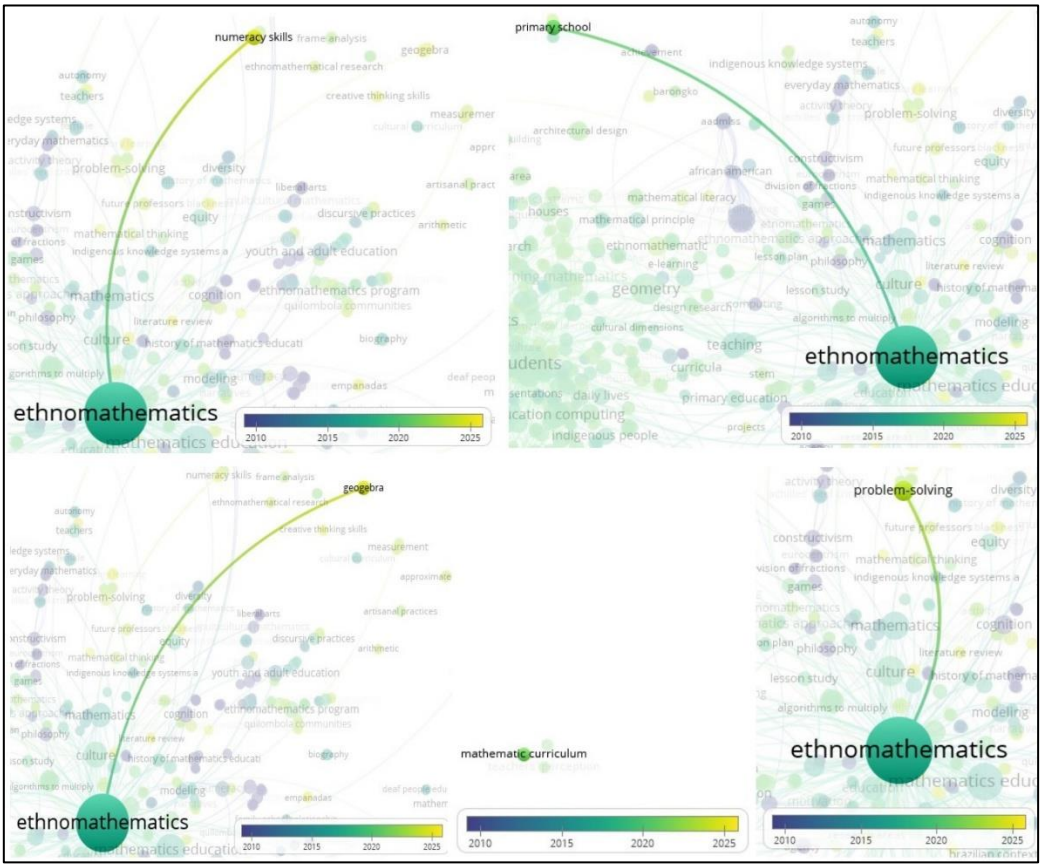

Figure 6: Potential keywords for future research

(Source: Author's elaboration using VOSviewer 1.6.20)

4. Discussion

4.1 Overviews and Global Trends in Ethnomathematics Studies

Regarding the number of publications and citations, Indonesia ranks first among the top-ten countries with the highest productivity in ethnomathematical publications. These findings indicate that research from Indonesia is not only prolific but also widely recognized by the academic community. Brazil ranks second in terms of the number of publications but leads in collaboration network strength, demonstrating the active involvement of Brazilian authors in international collaborations. This collaboration contributes to the broader dissemination and influence of their research. The United States, with the third-highest number of publications and the second-highest number of citations, reflects a high level of quality in its ethnomathematics research. Meanwhile, South Africa and Colombia, although producing fewer publications, have had a significant global impact on ethnomathematics, as evidenced by the number of citations they have received.

Rosa and Orey are critical figures in ethnomathematics due to their high productivity and extensive collaboration networks. Their active collaboration with other researchers has helped to disseminate their work widely. In contrast, D'Ambrosio and Prahmana stand out in terms of the impact of their research as seen in the high number of citations they have received even though they are less

prolific than Rosa and Orey. Moreover, Widada and Herawaty, noted for their strong collaboration networks, demonstrate close cooperation with other researchers, which enhances the visibility and dissemination of ethnomathematical studies.

Prahmana is recognized as the most influential author globally in ethnomathematics. His impact is reflected not only in the number of citations his work has received but also in the strength of his collaboration network. This finding indicates that his research is widely acknowledged and frequently produced through collaboration, enhancing its influence. Meanwhile, D'Ambrosio has more publications, but his network of collaborations is smaller, which may have limited his work's broader dissemination and recognition. In contrast, authors such as Rosa and Orey have extreme collaboration networks, likely contributing to the dissemination of their research. However, their citation counts are lower than those of other prominent authors. Similarly, despite having fewer publications, Eglash has made a significant impact, demonstrating the high quality and relevance of his research within the academic community.

Based on the perspective of publication trends, ethnomathematics indicates three distinct periods in its development. Initially, the field was highly specialized and had yet to gain significant global attention from researchers. The second period saw a noticeable increase in publications, reflecting growing interest in ethnomathematics worldwide and the recognition of the importance of linking cultural contexts to mathematics education. Lastly, in the third period, the number of publications surged, driven by factors such as rising awareness of the importance of integrating cultural diversity into education and curricula (Kyeremeh et al., 2023; Noerhasmalina & Hidayatulloh, 2023). This statement is supported by Rosa and Gavarrete (2017) who stated that integrating ethnomathematics into learning has enhanced students' understanding of mathematics and its relevance to social life. Furthermore, findings related to the decline in publications during 2021 and 2022 can be attributed to several factors, including shifting researcher priorities and challenges posed by the COVID-19 pandemic. The pandemic had an impact on the dynamics of academic publishing, reducing publications on non-COVID-19 research themes (Aviv-Reuven & Rosenfeld, 2021; Riccaboni & Verginer, 2022).

The findings on the 10 main topics of ethnomathematics reveal that the keyword "students" appears most frequently, reflecting numerous studies that position students as central subjects in ethnomathematics-based learning in schools. For example, Nst and Batubara (2024) found that ethnomathematics-based learning has been proved to enhance positive attitudes such as motivation, retention, and academic achievement. The frequent occurrence of the keyword "students" highlights their role as critical participants in mathematics learning in which cultural contexts are integrated into daily life. Hence, the keyword "mathematics learning", which also frequently appears, underscores the strong connection between ethnomathematics and education, particularly in linking mathematical concepts with local cultures. Several studies emphasize the importance of contextualizing mathematics learning within local cultures to foster student

understanding and engagement (Kusuma et al., 2023; Sari et al., 2023). The emergence of "Indonesia" as a prominent keyword points to the increasing attention to applying ethnomathematics in a country with rich cultural and ethnomathematical diversity. With its vast cultural heritage, Indonesia offers an essential context for exploring how different cultural elements can be incorporated into mathematics learning to deepen students' understanding of mathematical concepts (Kusuma et al., 2024; Lidinillah et al., 2022).

The appearance of the keyword "physics" is not due to a direct relationship between ethnomathematics and physical science but rather stems from several articles published in conference proceedings. Of the 644 articles in the metadata, 208 are from the *Journal of Physics*, indicating that ethnomathematical studies have been presented and disseminated globally across various scientific and academic forums. While ethnomathematics is rooted in cultural and educational contexts, it has garnered attention from the global academic community, mainly through international conferences. This finding aligns with Deda et al. (2024) who noted that the *Journal of Physics: Conference Series* is frequently used to disseminate ethnomathematical studies, indicating a broader scientific interest beyond mathematics education.

Additionally, the increasing trend of keywords such as "teaching", "ethnographic approaches", and "research methods" since 2014 points to a growing focus on research methodologies and culturally relevant teaching approaches in ethnomathematics. The use of these keywords illustrates that researchers are expanding their focus beyond student learning to include the development of more effective, culturally grounded teaching methods. Overall, the overviews and global trends indicate that ethnomathematics is evolving as a discipline that emphasizes student learning, teaching strategies, and research methodologies, and integrates culture into mathematics education.

4.2 Key Research Areas in Ethnomathematics

Recent ethnomathematical studies reflect vital themes that highlight the field's philosophical and cognitive foundations, emphasizing how patterns and knowledge are shaped within cultural contexts. Early research explored the emergence of ethnomathematics in mathematics education such as studies in the United States where considerations around ideological, content, and pedagogical diversity began to take hold (Furuto, 2014). Over time, research in ethnomathematics has shifted from theoretical discussions to practical applications in education.

Some of the main themes in the practical application of ethnomathematics focus on culturally diverse classroom environments and the training of educators to integrate ethnomathematics into conventional teaching methods. Integrating cultural knowledge into mathematics learning has proved effective in addressing the challenges of diverse classroom environments (Furuto, 2014; Machaba & Dhlamini, 2021). This integration requires specialized skills, leading to an increase in teacher training programs that focus on curriculum development and teaching strategies (Sunzuma & Maharaj, 2019). Additionally, the practical application of

ethnomathematics in education has begun to encompass numeracy skills and increased teacher self-confidence.

Based on an analysis of the 10 most frequently used keywords in ethnomathematics studies, the collected metadata indicate that ethnomathematics is a central focus in global mathematics education, emphasizing the strong connection between mathematics and culture. This fact is shown by the prominence of keywords such as "ethnomathematics", "students", and "mathematics education". These findings highlight the importance of a culture-based approach to mathematics learning in which students worldwide engage with mathematical concepts through their cultural contexts. Ethnomathematics integrates local values and traditional knowledge into the mathematics curriculum, enhancing students' understanding of foundational mathematical concepts. Moreover, the focus on the keyword "students" demonstrates that ethnomathematics research extends beyond theoretical discussions to practical classroom implementation. Additionally, the global introduction of ethnomathematics at various scientific conferences underscores this issue's importance (Deda et al., 2024).

Keywords such as "mathematical learning" and "mathematical concepts" highlight the significance of ethnomathematical studies in introducing fundamental mathematical ideas such as numbers, geometry, and algebra, particularly in diverse cultural contexts. Geometry, as a branch of mathematics frequently observed in traditional cultural practices, holds particular importance in ethnomathematics. Many cultures incorporate geometric patterns into crafts, architecture, and art, which can serve as practical teaching tools. The concept of "culture" in ethnomathematical studies strengthens the argument that a culturally informed approach to mathematics education can help students bridge their everyday experiences with more abstract academic concepts. Additionally, the use of "data collection" activities provides researchers with empirical evidence that demonstrates how mathematics is learned and applied across different cultures. Overall, these findings reaffirm the importance of ethnomathematical studies as an interdisciplinary approach that integrates mathematics, culture, science, pedagogy, and education.

4.3 Potential Themes for Future Ethnomathematics Studies

Several potential research themes that could be further explored and developed are emerging from the keyword mapping results. The first theme for further study is "technology integration in ethnomathematics-based mathematics learning". This research would focus on the integration of technology such as GeoGebra in mathematics instruction that incorporates a local cultural approach. A vital issue to explore is how GeoGebra can be effectively used as a visualization tool to explain mathematical concepts rooted in local culture. As supported by Dockendorff and Solar (2018), the use of GeoGebra in mathematics learning enhances visualization skills and facilitates mathematical processes such as conjecture-making. GeoGebra can serve as an interactive medium in mathematics education, linking mathematical concepts with cultural contexts. The research could also investigate the impact of GeoGebra on students' comprehension and

motivation in learning mathematics within a local cultural framework. Additionally, this subject could be explored across various educational levels, including elementary, secondary, and high school.

The second theme that can be explored in ethnomathematics research is "numeracy and problem-solving skills in ethnomathematics-based learning". This study could focus on how numeracy and mathematical problem-solving skills could be enhanced through ethnomathematical approaches. Problems rooted in local cultural contexts could be used as a focus to help students develop these skills. The study could also vary according to different educational levels. The third theme that could be investigated is the "development of an ethnomathematics-based school mathematics curriculum". This study could focus on designing a mathematics curriculum that integrates ethnomathematics at each school level. The emphasis would be on incorporating local cultural elements into mathematics content, making it more relevant to students' everyday lives. This curriculum development aims to provide students with a more contextual and meaningful approach to understanding mathematics.

The fourth theme that could be explored is "measurement and evaluation of ethnomathematics-based mathematics learning". This research could focus on developing tools or methods to assess the effectiveness of ethnomathematics-based learning across all educational levels. The study could also evaluate the extent to which ethnomathematical approaches enhance students' mathematical understanding. The final research theme is "professional development of teachers in ethnomathematical learning". This study could focus on training and professional development programs for mathematics teachers, equipping them to apply ethnomathematical approaches in the classroom. The research would examine how capacity-building initiatives can improve teachers' ability to integrate local cultural elements into mathematics instruction, ultimately fostering more meaningful learning experiences for students.

5. Conclusion

The expanding range of research themes in ethnomathematics necessitates further exploration to identify new areas for development. This study reveals that ethnomathematics is a rapidly growing field with an increasing variety of study themes worldwide. Indonesia has emerged as the most productive country in terms of ethnomathematical research, with the highest number of citations in Scopus-indexed journals. This productivity is supported by the country’s rich local cultural heritage, which provides a diverse context for integrating mathematics into school curricula. Brazil follows as the second most productive country in terms of publications but distinguishes itself through strong international collaborations in disseminating research.

Rosa was identified as the most prolific researcher, with 23 publications, 127 citations, and 36 collaboration networks, making him the author with the highest number of collaborations. Meanwhile, Prahmana was the most influential author in the field, with 23 publications, 225 citations, and 19 collaboration networks. Publication trends indicate that the peak years for ethnomathematical studies

were 2020 and 2023, with nearly 80 documents published annually during these periods.

Current ethnomathematics studies encompass several key themes, as reflected by commonly occurring keywords such as "ethnomathematics", "students", "mathematics education", "physics", "mathematics learning", "mathematical concepts", "culture", "data collection", and "mathematics". The term "ethnomathematics" is the most frequently used keyword, indicating that it serves as the central theme in nearly all publications and is linked to various other disciplines. Additionally, "students" and "mathematics education" appear as the most common keywords, highlighting that many publications focus on the roles of students and education within the context of ethnomathematical studies. Several promising themes for future research in ethnomathematics include integrating technology in ethnomathematics-based mathematics learning, improving numeracy and problem-solving skills, developing ethnomathematics-based school curricula, measuring and evaluating the effectiveness of ethnomathematics-based learning, and advancing the professional development of teachers in ethnomathematics-based education.

The findings of this study have several important implications for research, education, and policy. The increasing global interest in ethnomathematics suggests the need for stronger institutional support in integrating ethnomathematical approaches into formal education systems. The prominence of Indonesia and Brazil in this field indicates that countries with rich cultural traditions can make use of their local knowledge to enhance mathematics education. Furthermore, the identified research trends suggest that interdisciplinary collaboration—particularly between mathematics, education, and technology—can further strengthen the field. The growing role of digital tools such as GeoGebra and artificial intelligence in ethnomathematics-based learning highlights the need for educators to be equipped with technological and pedagogical expertise. Additionally, research focusing on curriculum development and teacher training can contribute to the broader adoption of ethnomathematics in diverse educational settings.

Despite these insights, this study had two primary limitations. First, it relied exclusively on the Scopus database, which, while including reputable international journals, may have narrowed the scope of analysis. Future studies should consider incorporating additional databases such as Web of Science, Dimensions, Lens, and PubMed, all of which are compatible with tools such as VOSviewer and Biblioshiny R. Second, the use of overly general search keywords may have resulted in retrieving broad information, making it difficult to identify emerging and more specific trends in the field. Future research could refine this approach by conducting a more focused bibliometric analysis using specific high-occurrence keywords from the main mapping results.

Based on these findings, several recommendations for future research can be made. One promising area of study is the application of GeoGebra in ethnomathematics-based learning. Future research could explore its role in

visualizing mathematical concepts rooted in local culture and assess its effectiveness in enhancing students' conceptual understanding. Additionally, studies could examine the broader impact of GeoGebra on ethnomathematics-based teaching across various educational levels from primary to higher education. Another potential research direction is the integration of artificial intelligence in ethnomathematics-based learning, focusing on adaptive learning systems that personalize instruction based on students' cultural backgrounds and mathematical proficiency.

In addition, further studies could investigate how ethnomathematics-based approaches enhance students' numeracy and problem-solving skills by comparing their effectiveness with conventional teaching methods. Research is also needed to develop a standardized framework for designing ethnomathematics-based curricula, ensuring alignment with national education standards while maintaining cultural relevance. Moreover, long-term impact studies could assess students' conceptual understanding, engagement, and retention of mathematical knowledge in ethnomathematics-based learning. Lastly, research on the professional development of teachers should examine effective training models that equip educators with the pedagogical skills necessary to implement ethnomathematics in diverse classroom settings.

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Ethics Statements
The authors confirm that this study does not require approval from an ethics committee. It does not involve experiments or research with humans or animals and uses publicly available data.

Conflict of Interest
The authors confirm that there are no conflicts of interest regarding the composition and publication of this study.

Declaration of Artificial Intelligence (AI) Usage
In the process of writing and editing this manuscript, the authors used artificial intelligence (AI) technologies to enhance the text's quality. Specifically, GPT-4o was employed to improve readability, ensuring clearer and more coherent writing. Additionally, Grammarly was used to correct grammatical errors and spelling, helping to elevate the manuscript to higher academic standards. The use of these tools was aimed at improving the manuscript's quality without altering its substance or intended meaning.

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