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# Inquiry Based Learning in Mathematics Education: A Bibliometric Study

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## Article Info

## Abstract

Inquiry Based Learning (IBL) has emerged as a transformative pedagogical approach in mathematics education, emphasizing student-centered exploration and critical thinking. This study conducts a bibliometric analysis to explore trends, influential contributors, and research themes in IBL within mathematics education. A total of 82 publications were retrieved from the Scopus database, covering the period from 2008 to 2024. Analytical tools such as biblioMagika® were employed for metric calculations, OpenRefine for data cleaning, and VOSviewer for network visualization. The analysis reveals a notable increase in IBL research after 2016, with a peak in 2024, driven by the integration of digital tools and the growing emphasis on problem-solving skills in mathematics education. The leading contributors include countries such as the United States, Australia, and the Netherlands, with institutions like the University of California and Utrecht University playing pivotal roles. Highly cited publications from authors such as Katja Maass and Sandra L. Laursen underscore the field's academic impact. Core research themes identified include constructivism, technology-enhanced learning, and mathematical modeling, with frequent keywords being "inquiry based learning," "mathematics education," and "problem-solving." Citation metrics indicate an h-index of 17 and an average citation rate of 11.38 per publication, reflecting the scholarly influence of IBL research. This comprehensive analysis offers valuable insights for educators, researchers, and policymakers, advocating for continued exploration of IBL's potential to enhance mathematical understanding and inquiry-driven learning outcomes.

## Introduction

The Fourth Industrial Revolution has profoundly influenced mathematics education, emphasizing critical thinking and collaborative learning, which are essential skills in modern education (Sen et al., 2021). Inquiry Based Learning (IBL) has emerged as a prominent method, innovative and student-centered approaches to meet contemporary learning demands (von Renesse & Wegner, 2023). By engaging students in problem-solving activities and mathematical investigations, IBL fosters deep mathematical understanding by encouraging students to explore, question, and construct knowledge through guided inquiry (Quinlan & Edwards, 2024.

The IBL approach plays a crucial role in creating active learning environments and fostering meaningful mathematical discourse across various educational settings. (Lupion-Cobos et al., 2021). IBL has proven effective in enhancing students' motivation and engagement, particularly when they explore mathematical concepts through hands-on activities, group discussions, and real-world problem-solving tasks (Gomez-Chacon et al., 2022). This approach highlights IBL's adaptability to diverse learning environments, enabling students to continue their mathematical inquiries beyond traditional classroom settings.

The implementation of IBL in mathematics education has also shown significant impacts across different educational contexts, from primary schools to higher education institutions. Countries such as Spain, Turkey, and Germany have incorporated IBL approaches to promote collaborative problem-solving and inquiry-driven learning experiences (Schallert et al., 2022). This adaptability allows educators to tailor IBL strategies to students' diverse learning needs, making mathematics more accessible and meaningful. Additionally, digital tools integrated with IBL practices enable students to engage in collaborative inquiry activities, facilitating peer learning and deeper mathematical discussions (von Renesse & Wegner, 2023).

Given the growing body of research on IBL in mathematics education, a comprehensive bibliometric analysis is crucial to map the research landscape and identify emerging trends, influential studies, and key contributors within this field (Gomez-Chacon et al., 2022). Such an analysis would offer valuable insights to educators, researchers, and policymakers, enabling them to leverage IBL effectively in mathematics teaching. With IBL's role expanding in both digital and traditional learning environments, this bibliometric overview will support future research and contribute to the advancement of inquiry-based practices in mathematics education.

## Literature Review

Inquiry Based Learning (IBL) has been widely acknowledged as a pedagogical approach that promotes student-centered learning, fostering engagement, critical thinking, and deeper mathematical understanding. Over the years, various conceptual models of IBL have emerged, each emphasizing different aspects of inquiry within mathematics education. Scholars have identified that IBL encompasses diverse instructional strategies, including problem-solving, mathematical modeling, and structured exploration, all of which encourage learners to engage in authentic mathematical inquiry (Şen et al., 2021). By enabling students to investigate problems, develop conjectures, and refine their reasoning through discourse, IBL serves as an effective alternative to traditional direct

instruction.

The effectiveness of IBL is often linked to its impact on students' attitudes and learning outcomes. Research by Radmehr et al. (2023) suggests that on the teaching of vertex coloring using an inquiry-based approach found that students exhibited higher engagement and a stronger grasp of graph theory concepts when exposed to inquiry-driven tasks. Similarly, a study conducted by Gómez-Chacón et al. (2024) suggests that IBL positively influences students' mathematical self-concept and perceived competence, leading to a more favorable disposition towards learning mathematics. Meta-analyses in the field further reinforce the idea that IBL contributes to deeper learning and enhances problem-solving abilities, particularly when implemented in structured and well-facilitated learning environments (Polanin et al., 2024).

Despite the reported benefits, integrating IBL into mathematics classrooms is not without challenges. Studies indicate that while some students thrive in inquiry-driven environments, others may struggle with the autonomy required, necessitating a careful balance between structured guidance and open-ended exploration (Huang et al., 2021). Teachers often face difficulties in designing inquiry-based lessons, as they require extensive professional development to shift from traditional teaching methods to more student-centered practices (Kiss, 2022). The success of IBL implementation also depends on contextual factors such as curriculum constraints, assessment methods, and students' readiness for independent exploration (Schallert et al., 2022).

The integration of digital tools has further influenced the implementation of IBL in mathematics education. The use of flipped classroom models, where students engage with instructional content before class and actively participate in inquiry-based activities during lessons, has shown promise in enhancing student engagement and learning outcomes (Schallert et al., 2021). Online platforms and digital simulations provide additional support for IBL by offering immediate feedback, enabling collaborative inquiry, and allowing students to revisit complex concepts at their own pace (Schallert et al., 2022). Such technological advancements have the potential to mitigate some of the implementation challenges associated with IBL, making it more accessible and adaptable across different educational settings.

As research on IBL continues to evolve, future studies should explore its long-term impact on students' mathematical development and professional readiness. Comparative investigations across various educational contexts can provide further insights into the most effective strategies for implementing IBL in diverse learning environments. Additionally, continued efforts are needed to refine instructional frameworks that support both student autonomy and structured guidance, ensuring that all learners benefit from inquiry-based mathematics education (Gómez-Chacón et al., 2024).

**Research Questions**

This paper presents a bibliometric analysis of Inquiry Based Learning (IBL) in mathematics education by focusing on six main research questions (RQs):

RQ 1: What is the current state of IBL in mathematics education research?

RQ 2: What notable patterns and emerging directions can be identified in recent publications on IBL in mathematics education?

RQ 3: Which journals are central to publishing influential research on IBL in mathematics education?

RQ 4: Which significant publications have contributed to shaping the conversation and progress of IBL in mathematics education research?

RQ 5: Which notable authors, institutions, and countries are leading advancements in IBL in mathematics education research?

RQ 6: What core research themes and focal areas support the advancement and expansion of IBL studies in mathematics education?

The comprehensive nature of this study provides an opportunity to thoroughly understand the scope of research on IBL in mathematics education. By employing bibliometric and network analysis techniques, this study establishes a deep understanding of the scholarly landscape, core themes, and clusters within this domain. The insights gained are crucial for guiding the development of more effective educational practices that leverage IBL, aligning with the continuously evolving technological and educational standards. Ultimately, this study aims to map the complex landscape of IBL in mathematics education. Through meticulous analysis, it provides a clear overview of the field's historical and current state, laying the foundation for future advancements. This endeavor is directed towards enhancing the effectiveness and fostering innovation in educational systems through the integration of IBL

## Methodology

This study employed data sourced from the Scopus database as of February 12, 2025. The selection of Scopus was a purposeful methodological choice, given its distinguished reputation as one of the most extensive and detailed abstract and citation databases for peer-reviewed literature. Scopus offers vast coverage across various disciplines, including scientific, technical, medical, and social sciences, which is essential for investigating Inquiry Based Learning (IBL) in mathematics education. The database's comprehensive inclusion of fields such as computer science, social sciences, engineering, arts, and humanities ensures a diverse and reliable dataset. Known for its rigorous quality controls and broad geographical reach, Scopus serves as an ideal tool for conducting an in-depth bibliometric analysis. Additionally, its capacity to provide extensive metadata, including citation details and author affiliations, reinforced its selection as the primary data source for this study (Aghaei Chadegani et al., 2013). The collected data encompassed a range of variables, such as document types, source types, languages, subject areas, publication trends, average authorship per document, institutional contributions, publication distribution by country, and prominent keywords, among other aspects.

### Search Strategy

This review employed the modified PRISMA guidelines (Haddaway et al., 2022) to structure the systematic assessment of research studies (Moher et al., 2009). The search query "Self Directed Learning" AND "Math*" AND "("Educat*" OR "Learn*" OR "Teach*" OR "Pedagog*")" was used in the Scopus database, followed by

the application of subject-specific filters. The study's scope and selection criteria included search field, time frame, source type, and document type to ensure the exclusion of non-relevant studies. This process initially identified 184 documents (see Figure 1). Subsequently, abstracts were reviewed to filter out records lacking topical relevance. Following this screening, the final dataset retained 32 documents related to self-directed learning in mathematics education.
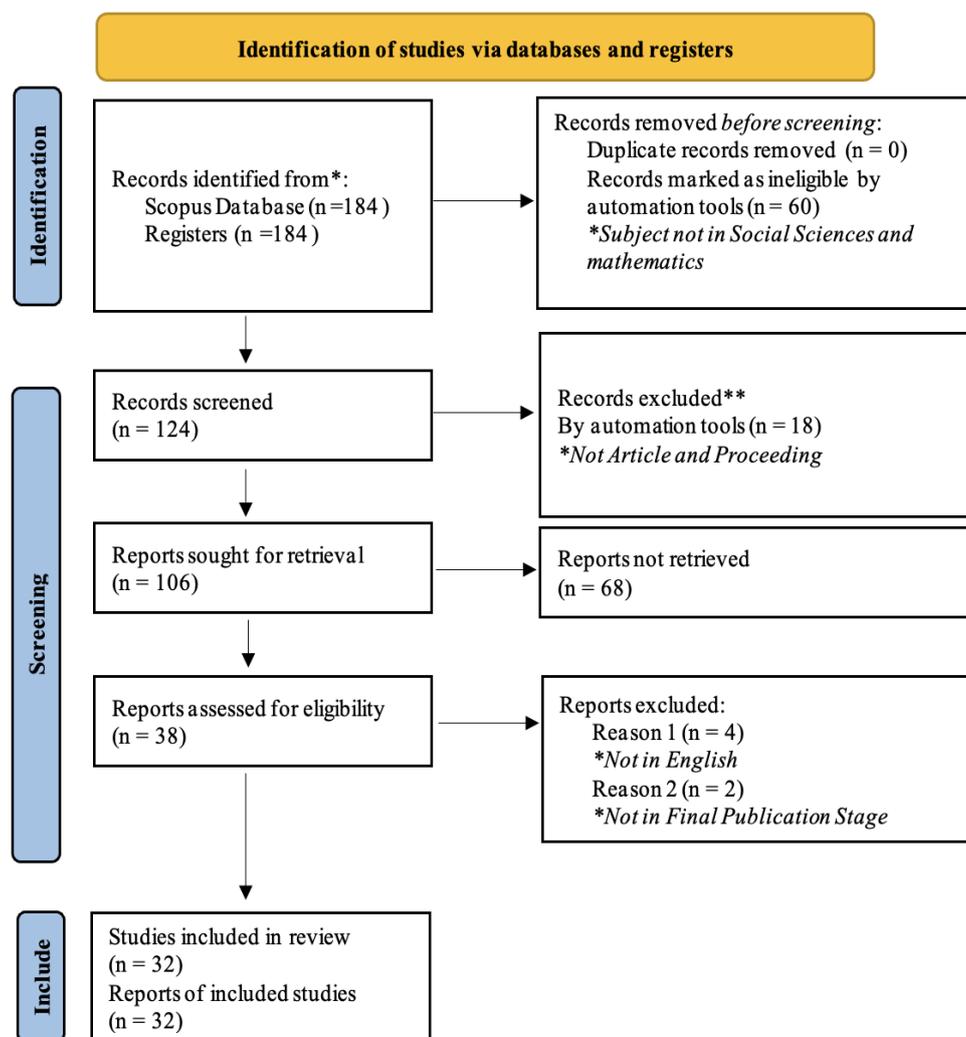


Figure 1. Flow Diagram of The Search Strategy

**Data Cleaning and Harmonization**

Data cleaning and harmonization are crucial in bibliometric analysis, ensuring accuracy and reliability. This study used OpenRefine and biblioMagika® (Ahmi, 2023), tools designed for refining bibliographic data such as author names, affiliations, and keywords, which ensured data precision and uniformity amid diverse research outputs. The process began with downloading Scopus data in CSV format, targeting specific files and columns for correction using clustering techniques. For advanced analysis, biblioMagika® calculated indicators like Total Publications (TP), Number of Contributing Authors (NCA), Number of Cited Publications (NCP), Total Citations (TC), Citations per Publication (C/P), Citations per Cited Publication (C/CP), Citations per Author (C/A), Authors

per Publication (A/P), Citations per Year (C/Y), h-index, g-index, m-index, and the Citation Sum within the h-Core across categories such as year, source, authors, institutions, and countries. biblioMagika® also identified missing data, allowing manual completion to improve dataset comprehensiveness. These tools strengthened the analysis, enhancing the dataset's clarity and reliability for exploring self-directed learning in mathematics education.

**Data Analysis**

The data analysis was structured to directly address the research questions. The authors' approach involved mapping the current state of Inquiry Based Learning (IBL) research in mathematics education, focusing on document types, source categories, languages, subject areas, and citation metrics. The findings were presented across several criteria, such as annual publication volume, contributions from leading authors, prominent institutions, key countries, and influential source titles, highlighting major contributors and trends within the field. To assess the impact and significance of the publications, bibliometric indicators were used, including total publications, number of cited papers, total citations, citations per publication, citations per cited publication, h-index, g-index, m-index, and total citation count within the h-core. Additionally, to uncover dominant themes and concepts in this field, the authors applied methods like co-occurrence network analysis, thematic mapping, and factorial analysis to visualise the authors' keywords. These visualisations allowed for the identification of topic clusters, detection of patterns, and exploration of connections among various research subfields.

**Tools**

The study utilized a range of tools to perform a comprehensive bibliometric analysis. Microsoft Excel was used for initial data cleaning and organization, while biblioMagika® streamlined the cleaning, harmonization, and standardization of data on authors' affiliations and countries. OpenRefine was applied specifically to harmonize and clean data for authors' keywords. Once the data was prepared, VOSviewer generated informative visual representations of the research findings, with Mendeley serving as the reference manager. This combination of tools and techniques enabled a thorough and rigorous examination of the field of IBL in mathematics education.

# Results

In the upcoming results section, the authors will present an in-depth examination of the research landscape for Inquiry Based Learning (IBL) in mathematics education. This detailed analysis will address the research questions (RQs), yielding a deep understanding of the field. Through this focused analysis, the authors are committed to delivering a detailed and insightful overview of the IBL in mathematics education domain, contributing valuable knowledge for scholars, practitioners, and decision-makers.

**Current State of IBL in Mathematics Education Research**

To address the initial research question, which aims to map the current state of IBL in mathematics education

research, the authors will analyze the distribution of publications across multiple factors, including document type, source type, languages, and subject areas. Additionally, citation metrics will be assessed to gauge the impact and significance of these contributions within the field of IBL in mathematics education. The data were first organized by document type, encompassing a range of formats such as articles, conference papers, book chapters, and review articles. Conference papers often present research findings shared at scholarly conferences, with some subsequently published in proceedings or as book chapters.

Through an extensive analysis covering the period from 2008 to 2024, a comprehensive dataset in Table 1 highlights significant academic contributions, totaling 82 publications that demonstrate a robust research trajectory. This body of work involves a wide network of 242 contributing authors, underscoring the collaborative nature of scholarly research. The count of 66 cited papers points to the substantial reach and influence of these contributions within the academic community. An impressive total of 933 citations further reinforces the impact of this research over the 18 citable years. This research collection has garnered an average of 11.38 citations per paper, indicating consistent recognition across the published works. Furthermore, for cited papers exclusively, the average citation per paper rises to 14.14, reflecting concentrated acknowledgment by peers and highlighting the higher impact of those works that have been referenced. These metrics collectively illustrate not only the volume of research output but also emphasize the quality and influence of the work produced, providing a comprehensive view of the academic footprint of this body of scholarly literature.

Table 1. Citation Metric

| Main Information | Data |
|---|---|
| Publication Years | 2008 - 2024 |
| Total Publications | 82 |
| Citable Year | 18 |
| Number of Contributing Authors | 242 |
| Number of Cited Papers | 66 |
| Total Citations | 933 |
| Citation per Paper | 11.38 |
| Citation per Cited Paper | 14.14 |
| Citation per Year | 58.31 |
| Citation per Author | 3.86 |
| Author per Paper | 2.95 |
| Citation sum within h-Core | 869 |
| h-index | 17 |
| g-index | 28 |
| m-index | 0.944 |

**Notable Patterns and Emerging Directions of IBL in Mathematics Education**

To address the second research question, the authors examined the developmental trajectory of this field. The

earliest recorded publication in 2008 marks the beginning of research in this area, followed by sporadic publications until 2015. A noticeable growth occurred from 2016 onwards, reaching a peak in 2024 with 16 publications (as shown in Figure 2 and Table 2). The visualization of total publications and citations reveals fluctuating trends, with notable citation peaks in 2014 (116 citations) and 2018 (129 citations), despite relatively fewer publications in those years. The line graph reflects these citation trends, signifying the evolving scholarly impact over time.The increase in total publications is accompanied by a rise in the Number of Contributing Authors (NCA), which reached 16 in 2024, indicating a growing research community. This trend suggests that the field is expanding, with increasing contributions from diverse researchers. The multidisciplinary nature of this research, integrating elements from various domains, is evident in the sustained interest and collaboration patterns observed.
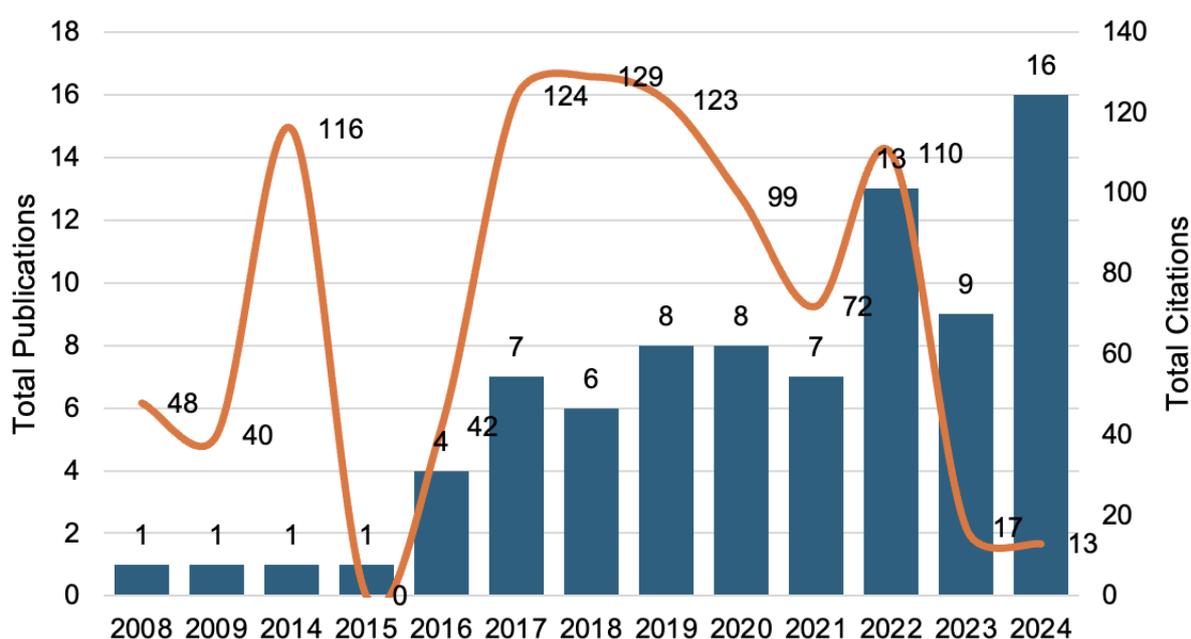


Figure 2. Total Publications and Citations by Year (as data is only available up to 12 February 2025)

In terms of impact, the h-index and g-index, as shown in Table 2, provide insights into the scholarly influence of the field. The h-index stands at 41, while the g-index is 59, demonstrating a substantial body of highly cited works. However, the m-index exhibits fluctuations, with a peak of 1.5 in 2022, reflecting a period of high-impact publications. These citation metrics highlight the growing importance of this research domain, although variations in citation patterns suggest that further analysis is needed to understand shifts in scholarly influence. The trends underscore the field's increasing relevance, positioning it as a significant area within academic research.

Table 2. Yearly Output of Publications

| Year | TP | NCA | NCP | TC | C/P | C/CP | h | g | m |
|------|----|-----|-----|-----|--------|--------|---|---|-------|
| 2008 | 1 | 1 | 1 | 48 | 48.00 | 48.00 | 1 | 1 | 0.056 |
| 2009 | 1 | 1 | 1 | 40 | 40.00 | 40.00 | 1 | 1 | 0.059 |
| 2014 | 1 | 1 | 1 | 116 | 116.00 | 116.00 | 1 | 1 | 0.083 |

| Year | TP | NCA | NCP | TC | C/P | C/CP | h | g | m |
|------|-----|-----|-----|-----|-------|-------|-----|-----|-------|
| 2015 | 1 | 1 | 0 | 0 | 0.00 | 0.00 | 0 | 0 | 0.000 |
| 2016 | 4 | 4 | 4 | 42 | 10.50 | 10.50 | 3 | 4 | 0.300 |
| 2017 | 7 | 7 | 7 | 124 | 17.71 | 17.71 | 4 | 7 | 0.444 |
| 2018 | 6 | 6 | 6 | 129 | 21.50 | 21.50 | 5 | 6 | 0.625 |
| 2019 | 8 | 8 | 7 | 123 | 15.38 | 17.57 | 5 | 8 | 0.714 |
| 2020 | 8 | 8 | 8 | 99 | 12.38 | 12.38 | 6 | 8 | 1.000 |
| 2021 | 7 | 7 | 7 | 72 | 10.29 | 10.29 | 5 | 7 | 1.000 |
| 2022 | 13 | 13 | 12 | 110 | 8.46 | 9.17 | 6 | 10 | 1.500 |
| 2023 | 9 | 9 | 6 | 17 | 1.89 | 2.83 | 2 | 3 | 0.667 |
| 2024 | 16 | 16 | 6 | 13 | 0.81 | 2.17 | 2 | 3 | 1.000 |
| Grand Total | 82 | 82 | 66 | 933 | 11.38 | 14.14 | 41 | 59 | 7.448 |

Notes: TP = total number of publications; NCA = number of contributing authors; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index.

* Publication data for the year 2025 is only up until 12 February 2025.

**Journal of IBL in Mathematics Education Research**

Table 3 identifies the leading journal contributing to IBL in mathematics education, focusing on publications with two or more documents. Problems, Resources, and Issues in Mathematics Undergraduate Studies leads with a total publication count (TP) of 7 and a total citation count (TC) of 13, signifying its contribution to IBL research. Despite a modest average citation per publication (C/P) of 1.86, the journal achieves an h-index of 3 and a g-index of 3, indicating consistent research impact.

The International Journal of Science and Mathematics Education follows closely with 6 publications and a high total citation count (TC) of 80. The journal demonstrates strong citation performance with average citations per publication (C/P) and per cited publication (C/CP) both at 13.33. Its h-index of 5 and g-index of 6 reflect a substantial and sustained research impact within IBL studies. ZDM – Mathematics Education stands out with 4 publications and a total citation count (TC) of 77, achieving the highest average citations per publication (C/P) and per cited publication (C/CP) at 19.25. Its h-index of 4 and g-index of 4 further highlight its significant contribution to IBL research.

Frontiers in Education and Education Sciences are also notable contributors, with total citation counts of 28 and 19, respectively. Although Frontiers in Education has a higher average citation per publication (C/P) of 5.60 compared to Education Sciences (4.75), both journals contribute meaningfully, with h-indices of 3 and 2, respectively. The International Journal of STEM Education demonstrates remarkable citation efficiency, with only 2 publications generating 56 citations, resulting in a C/P of 28.00, the highest among all listed journals. Despite its limited publication count, its h-index and g-index, both at 2, indicate a strong impact per article.

Additionally, the Eurasia Journal of Mathematics, Science and Technology Education, Journal on Efficiency and Responsibility in Education and Science, and Mathematics Enthusiast contribute to IBL discourse, though with lower total publication and citation counts. However, the Eurasia Journal of Mathematics, Science and Technology Education shows a relatively strong average citation per publication (C/P) of 12.50, emphasizing its impact per contribution. This analysis highlights the diverse range of publication venues contributing to IBL research in mathematics education. The data underscores the importance of journals with both high publication output and strong citation impact. Such insights assist researchers and institutions in identifying key publication venues that shape advancements in IBL pedagogy, thereby supporting innovation and the advancement of mathematics education.

Table 3. Journal with Two (2) or More Publications

| Source Title | TP | NCA | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|---|
| Problems, Resources, and Issues in Mathematics Undergraduate Studies | 7 | 7 | 5 | 13 | 1.86 | 2.60 | 3 | 3 | 0.273 |
| International Journal of Science and Mathematics Education | 6 | 6 | 6 | 80 | 13.33 | 13.33 | 5 | 6 | 0.833 |
| Frontiers in Education | 5 | 5 | 3 | 28 | 5.60 | 9.33 | 3 | 5 | 0.600 |
| Education Sciences | 4 | 4 | 2 | 19 | 4.75 | 9.50 | 2 | 4 | 0.500 |
| International Journal of Mathematical Education in Science and Technology | 4 | 4 | 4 | 43 | 10.75 | 10.75 | 3 | 4 | 0.333 |
| ZDM - Mathematics Education | 4 | 4 | 4 | 77 | 19.25 | 19.25 | 4 | 4 | 0.571 |
| International Journal of Evaluation and Research in Education | 3 | 3 | 3 | 13 | 4.33 | 4.33 | 2 | 3 | 0.333 |
| International Journal of STEM Education | 2 | 2 | 2 | 56 | 28.00 | 28.00 | 2 | 2 | 0.250 |
| Eurasia Journal of Mathematics, Science and Technology Education | 2 | 2 | 1 | 25 | 12.50 | 25.00 | 1 | 2 | 0.200 |
| Journal on Efficiency and Responsibility in Education and Science | 2 | 2 | 2 | 4 | 2.00 | 2.00 | 1 | 2 | 0.167 |
| Mathematics Enthusiast | 2 | 2 | 1 | 4 | 2.00 | 4.00 | 1 | 2 | 0.167 |

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = index

**Significant Publications of IBL in Mathematics Education**

Table 4 highlights the top five publications in the field of IBL in mathematics education, showcasing influential works that have significantly contributed to this area. Leading the list is Maass (2014), whose study on the long-term effects of IBL in college mathematics has received 116 citations, with an average of 9.67 citations per year. This work underscores the impact of IBL on mathematical understanding and its long-lasting benefits for learners.

Following this is the article by Plaxco (2018), which investigates how creativity, autonomy, and visual reasoning

contribute to cognitive learning through a STEAM hands-on IBL module. With 85 citations and an average of 10.63 citations per year, this study highlights the integration of IBL with interdisciplinary approaches to enhance learning outcomes. Additionally, Caliz (2008) contributes to the discourse with research on using IBL to strengthen statistical understanding in biology laboratory courses. Although the oldest publication in this list, it has accrued 48 citations, averaging 2.67 citations per year, reflecting its relevance in promoting cross-disciplinary applications of IBL.

Lastly, Kostiainen (2019) explores the role of IBL in promoting active citizenship through mathematics teaching, receiving 43 citations with an average of 6.14 citations per year. This work highlights the potential of IBL in fostering civic awareness alongside mathematical competence. Collectively, these highly cited articles illustrate the growing body of research on IBL in mathematics education, emphasizing its effectiveness in fostering critical thinking, interdisciplinary learning, and student engagement. The consistent citation activity across these publications underscores their lasting impact in advancing educational theory and practice within the IBL framework.

Table 4. Top Five (5) Publication Articles

| No. | Author(s) | Title | TC | C/Y |
|---|---|---|---|---|
| 1 | Maass (2014) | Assessing Long-Term Effects of Inquiry-Based Learning: A Case Study from College Mathematics | 116 | 9.67 |
| 2 | Plaxco (2018) | How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module | 85 | 10.63 |
| 3 | Martin (2017) | What is inquiry-based learning? | 55 | 6.11 |
| 4 | Caliz (2008) | Teaching statistics in biology: Using inquiry-based learning to strengthen understanding of statistical analysis in biology laboratory courses | 48 | 2.67 |
| 5 | Kostiainen (2019) | Promoting active citizenship in mathematics teaching | 43 | 6.14 |

**Notable Authors, Institutions and Countries of IBL in Mathematics Education Research**

Table 5 presents the top-contributing authors in the field of IBL in mathematics education, identifying those with two or more publications. Leading this group is Katja Maass from the University of Education Freiburg, Germany, with a total of 3 publications and 3 cited publications, resulting in 75 total citations. Maass's work yields an average of 25.00 citations per publication (C/P), with an h-index of 3, g-index of 3, and an m-index of 0.429, underscoring her substantial academic influence.

Following Maass is Emily Cilli-Turner from the University of Washington, United States, with 2 publications and 2 cited publications, garnering 20 total citations. Cilli-Turner achieves an average of 10.00 citations per

publication, with an h-index of 2, g-index of 2, and an m-index of 0.222, reflecting her contribution to IBL research within the U.S. context. Sandra L. Laursen from the University of Colorado Boulder, United States, stands out with 2 publications and 2 cited publications, receiving 136 total citations. Laursen achieves an average of 68.00 citations per publication, with an h-index of 2, g-index of 2, and an m-index of 0.167, highlighting her significant impact in IBL research despite a smaller publication count.

Oi-Lam Ng from The Chinese University of Hong Kong contributes 2 publications with 2 cited publications and a total of 55 citations. Ng achieves an average of 27.50 citations per publication, with an h-index of 2, g-index of 2, and an m-index of 0.333, reflecting her influence within the Hong Kong research community. From The University of Queensland, Australia, Katie Makar has 2 publications and 2 cited publications, resulting in 11 citations, with an average of 5.50 citations per publication. Makar holds an h-index of 2, a g-index of 2, and an m-index of 0.667, indicating consistent contributions to IBL research in Australia.

Stefanie Schallert and Zsolt Lavicza from Johannes Kepler University, Austria, both have 2 publications and 2 cited publications, each with 36 total citations and an average of 18.00 citations per publication. Both maintain h-indices of 2, g-indices of 2, and m-indices of 0.500, highlighting their collaborative contributions to IBL research in Austria. Additionally, Michiel Doorman from Utrecht University, Netherlands, has 2 publications and 2 cited publications, with 52 total citations, averaging 26.00 citations per publication. Doorman's h-index of 2, g-index of 2, and m-index of 0.286 reflect his contributions to IBL research in the Netherlands.

Lastly, Ellen Vandervieren from the University of Antwerp, Belgium, has 2 publications and 2 cited publications with 36 citations, averaging 18.00 citations per publication. Vandervieren holds an h-index of 2, g-index of 2, and an m-index of 0.500, underscoring her contributions to IBL research in Belgium. Collectively, these authors demonstrate a strong international and collaborative research presence in IBL in mathematics education, underscoring the interdisciplinary impact of this field.

Table 5. Top-contributing Authors that Published More than Two (2) Documents

| Full Name | Current Affiliation | Country | TP | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|---|---|
| Maass, Katja | University of Education Freiburg | Germany | 3 | 3 | 75 | 25.00 | 25.00 | 3 | 3 | 0.429 |
| Cilli-Turner, Emily | University of Washington | United States | 2 | 2 | 20 | 10.00 | 10.00 | 2 | 2 | 0.222 |
| Laursen, Sandra L. | University of Colorado Boulder | United States | 2 | 2 | 136 | 68.00 | 68.00 | 2 | 2 | 0.167 |
| Ng, Oi-Lam | The Chinese University of Hong Kong | Hong Kong | 2 | 2 | 55 | 27.50 | 27.50 | 2 | 2 | 0.333 |
| Makar, Katie | The University of Queensland | Australia | 2 | 2 | 11 | 5.50 | 5.50 | 2 | 2 | 0.667 |

| Full Name | Current Affiliation | Country | TP | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|---|---|
| Schallert, Stefanie | Johannes Kepler University Linz | Austria | 2 | 2 | 36 | 18.00 | 18.00 | 2 | 2 | 0.500 |
| Lavicza, Zsolt | Johannes Kepler University Linz | Austria | 2 | 2 | 36 | 18.00 | 18.00 | 2 | 2 | 0.500 |
| Doorman, Michiel | Utrecht University | Netherlands | 2 | 2 | 52 | 26.00 | 26.00 | 2 | 2 | 0.286 |
| Vandervieren, Ellen | University of Antwerp | Belgium | 2 | 2 | 36 | 18.00 | 18.00 | 2 | 2 | 0.500 |

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = index

Other than that, Table 6 presents the top-contributing institutions in the field of IBL in mathematics education, listing those with at least five publications. Leading the table is the University of California, United States, with a total of 11 publications and 11 cited publications, accumulating 264 total citations. The institution achieves an average of 24.00 citations per publication (C/P) and per cited publication (C/CP), with an h-index and g-index of 11, and an m-index of 1.100, reflecting its significant research impact in IBL.

Following closely is Utrecht University, Netherlands, with 9 publications and 9 cited publications, garnering 198 total citations. With an average of 22.00 citations per publication, this institution demonstrates a strong influence in IBL research, supported by an h-index and g-index of 9, along with an m-index of 1.286, the highest among the listed institutions. The University of Jyväskylä, Finland, contributes 7 publications with 7 cited publications but has a relatively lower citation impact, accumulating 14 total citations and an average of 2.00 citations per publication. The institution holds an h-index of 2, a g-index of 3, and an m-index of 0.667, suggesting its developing but growing role in IBL research.

The University of Western Australia, with 6 publications and 6 cited publications, achieves 72 total citations, averaging 12.00 citations per publication. Its h-index and g-index of 6, along with an m-index of 0.600, indicate a consistent research presence in IBL. Similarly, the University of Nebraska, United States, with 5 publications and 5 cited publications, has accumulated 63 citations, averaging 12.60 citations per publication, supported by an h-index of 2 and a g-index of 5. Notably, the University of Colorado Boulder, United States, demonstrates a strong citation impact despite having only 5 publications. It has received 273 total citations, achieving the highest average citations per publication (C/P) and per cited publication (C/CP) at 54.60. With an h-index of 4, a g-index of 5, and an m-index of 0.333, this institution showcases the high influence of its contributions to IBL research.

Table 6. Top-contributing Institutions with a Minimum of Five (5) Publications

| Institution Name | Country | TP | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|---|
| University of California | United States | 11 | 11 | 264 | 24.00 | 24.00 | 11 | 11 | 1.100 |
| Utrecht University | Netherlands | 9 | 9 | 198 | 22.00 | 22.00 | 9 | 9 | 1.286 |
| University of Jyväskylä | Finland | 7 | 7 | 14 | 2.00 | 2.00 | 2 | 3 | 0.667 |

| Institution Name | Country | TP | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|---|
| University of Western Australia | Australia | 6 | 6 | 72 | 12.00 | 12.00 | 6 | 6 | 0.600 |
| University of Nebraska | United States | 5 | 5 | 63 | 12.60 | 12.60 | 2 | 5 | 0.222 |
| University of Colorado Boulder | United States | 5 | 5 | 273 | 54.60 | 54.60 | 4 | 5 | 0.333 |

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = index

Finally, Figure 3 and Table 7 present an international overview of IBL research contributions in mathematics education, highlighting countries with ten or more publications. The United States leads with 64 publications and a total citation count of 56, achieving an h-index of 18.68, a g-index of 21, and an m-index of 32, underscoring its significant scholarly impact. The average citations per publication (C/P) for the United States is 1046, with an average citation per cited publication (C/CP) of 16.34, demonstrating its authoritative role in IBL research.
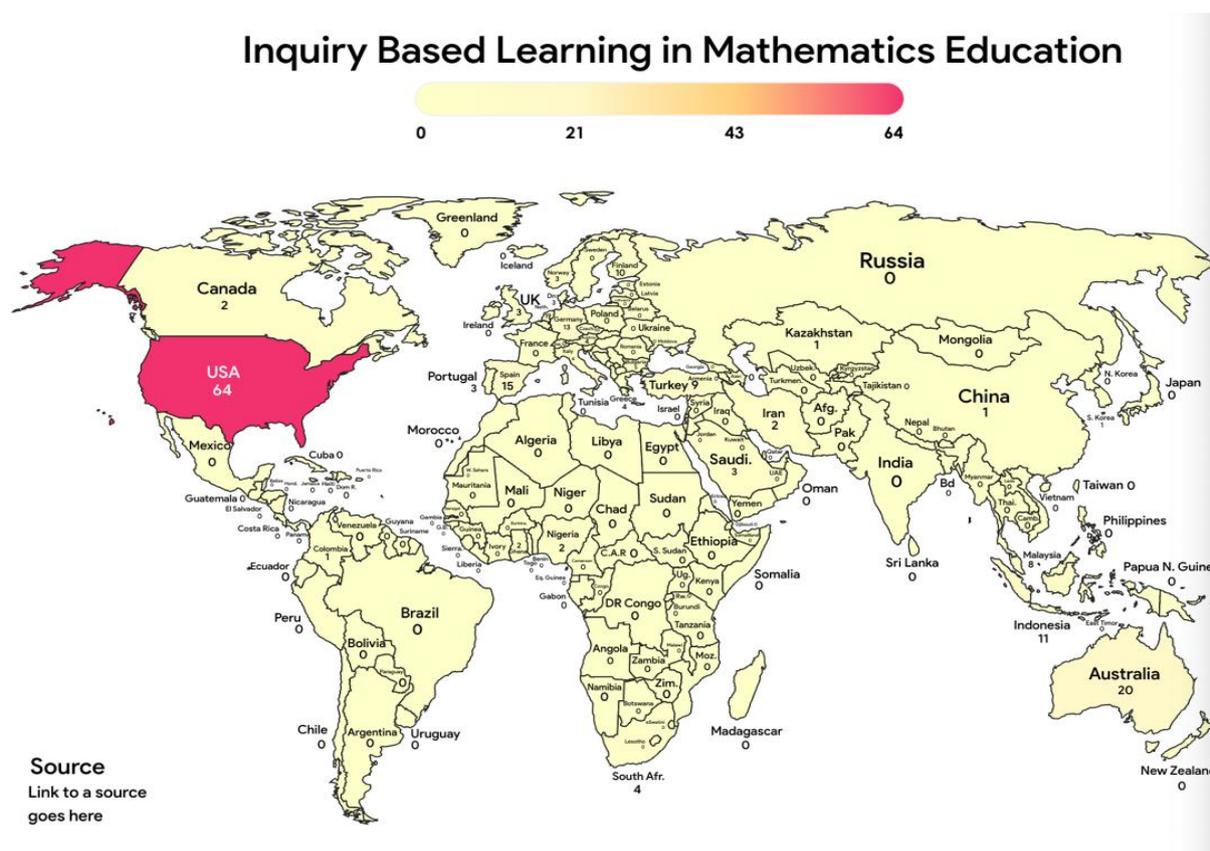


Figure 3. International Overview of IBL Research Publications in Mathematics Education

Australia follows with 20 publications, accumulating 20 citations, with an h-index of 15.00, a g-index of 12, and an m-index of 17. Australia records 300 citations per publication (C/P) and 15.00 citations per cited publication (C/CP), indicating its substantial contribution to the field. The Netherlands ranks third with 19 publications, totaling 19 citations, with an h-index of 19.68, a g-index of 10, and an m-index of 19, alongside an impressive 374 average citations per publication (C/P) and 19.68 citations per cited publication (C/CP).Spain contributes 15 publications, achieving 14 citations, with an h-index of 4.21, a g-index of 4, and an m-index of 7, reflecting steady research efforts with 59 citations per publication and 3.93 citations per cited publication.

Germany has 13 publications, with 13 citations, an h-index of 18.85, a g-index of 8, and an m-index of 13, demonstrating strong academic performance with 245 citations per publication and 18.85 citations per cited publication. Indonesia contributes 11 publications, accumulating 8 citations, with an h-index of 21.50, a g-index of 4, and an m-index of 11, showcasing notable impact in the region. The average citations per publication is 172, with 15.64 citations per cited publication. Finland and the Czech Republic each contribute 10 publications, with Finland achieving 10 citations, an h-index of 18.50, and a g-index of 2, while the Czech Republic has 7 citations, an h-index of 2.14, and a g-index of 3. This data, including h-index, g-index, and m-index, highlights the global diversity and academic impact of research on IBL in mathematics education.

Table 7. Top-Contributing Countries that Produced Ten (10) or More Publications

| Country | TP | NCP | TC | C/P | C/CP | h | g | m |
|---|---|---|---|---|---|---|---|---|
| United States | 64 | 24 | 56 | 1046 | 16.34 | 18.68 | 21 | 32 |
| Australia | 20 | 10 | 20 | 300 | 15.00 | 15.00 | 12 | 17 |
| Netherlands | 19 | NR | 19 | 374 | 19.68 | 19.68 | 10 | 19 |
| Spain | 15 | 2 | 14 | 59 | 3.93 | 4.21 | 4 | 7 |
| Germany | 13 | NR | 13 | 245 | 18.85 | 18.85 | 8 | 13 |
| Indonesia | 11 | 51 | 8 | 172 | 15.64 | 21.50 | 4 | 11 |
| Finland | 10 | NR | 10 | 185 | 18.50 | 18.50 | 2 | 10 |
| Czech Republic | 10 | NR | 7 | 15 | 1.50 | 2.14 | 3 | 3 |

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = index

**Core Research Themes and Focal Areas of IBL in Mathematics Education Research**

The author keyword network in Figure 4 provides a detailed analysis of the core research themes and their focal areas of IBL in the context of mathematics education. This network, constructed based on keywords with a minimum of three occurrences, offers a comprehensive perspective on how major themes intersect and inform one another. At the center of the network, "inquiry based learning" emerges as the dominant node, highlighting its central role in research on mathematics education. The surrounding clusters illustrate the diverse and interconnected subfields within IBL studies.

One prominent cluster is centered around "constructivism" and "active learning," reflecting the theoretical underpinnings of IBL. These themes emphasize the role of students as active participants in their learning process, constructing knowledge through exploration and problem-solving. Closely linked to this cluster is "technology-enhanced learning," which explores the integration of digital tools to support inquiry-based instruction, further reinforcing the shift toward interactive and student-centered mathematics education.

Another significant research cluster focuses on "problem-solving," a core component of IBL, demonstrating how inquiry-based methods enhance students' ability to engage with complex mathematical tasks. This cluster is connected to "professional development," indicating the role of teacher training in effectively implementing IBL strategies in classrooms. The cluster on "mathematics education" encompasses various related themes, including

"student-centered learning," "STEM education," and "design research." This grouping highlights the broader educational applications of IBL, extending beyond mathematics to interdisciplinary learning approaches. The emphasis on STEM education further underscores the relevance of IBL in fostering critical thinking and problem-solving skills essential for scientific and technological advancements.

Another notable cluster links "motivation," "gender," and "interaction," suggesting a growing interest in how IBL affects student engagement and participation across different demographics. This reflects ongoing discussions on the inclusivity and accessibility of inquiry-based methods in diverse educational contexts. Additionally, the network reveals a strong connection to "mathematical modeling," emphasizing the application of IBL in real-world problem-solving and analytical reasoning. This theme highlights the practical benefits of inquiry-based methods in helping students develop a deeper understanding of mathematical concepts.

In summary, the co-occurrence network illustrated in Figure 4 maps out the interconnected research themes within IBL in mathematics education. Each cluster represents a unique dimension of this field, collectively highlighting the breadth and depth of current research efforts. This network not only captures prevailing research trends but also serves as a framework for guiding future inquiries, emphasizing the transformative role of IBL in mathematics education.
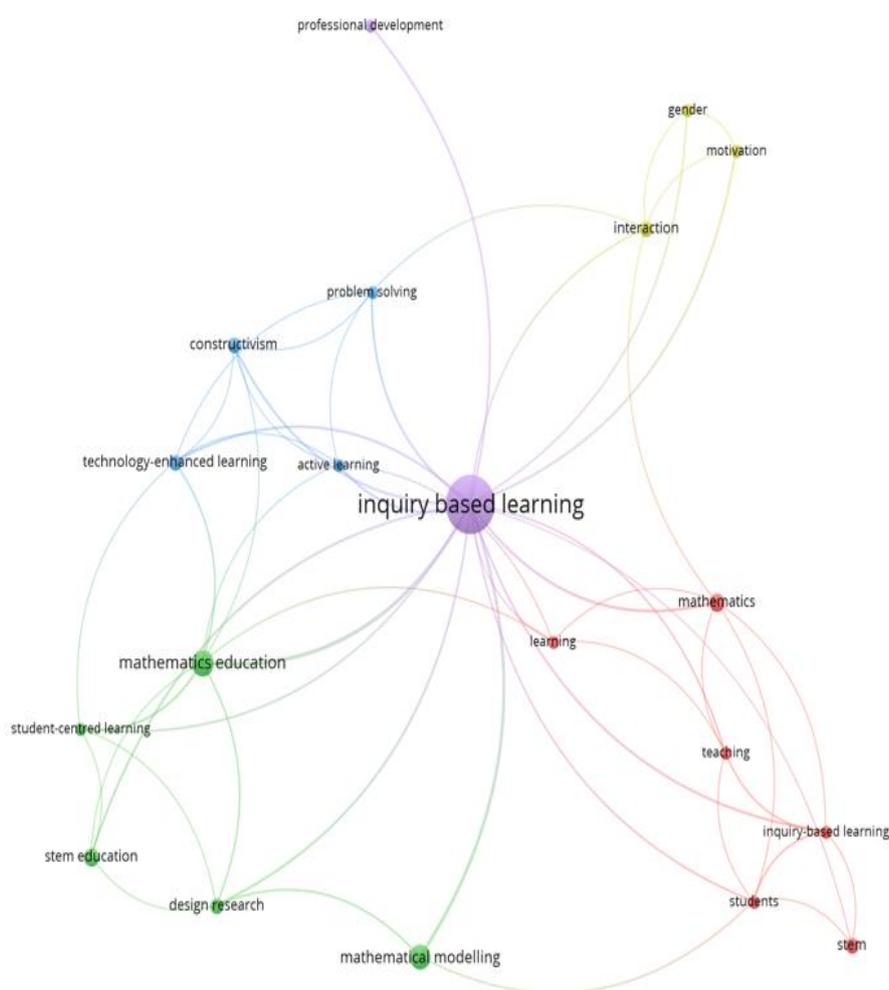


Figure 4. Author Keyword Network with a Minimum of Three Occurrences

## Discussion and Conclusion

This bibliometric analysis of Inquiry Based Learning (IBL) in mathematics education from 2008 to 2024 highlights significant research growth, especially from 2016 onward, indicating increasing scholarly engagement (Schallert et al., 2022; Gomez-Chacon et al., 2024). Also, global disruptions can accelerate digital learning adoption, consistent with Lupión-Cobos et al. (2021), who observed shifts in digital IBL practices. The United States, Australia, and the Netherlands emerge as primary contributors to IBL research, driven by strong institutional engagement (von Renesse & Wegner, 2023). Leading institutions such as the University of California and Utrecht University demonstrate high research impact (Maass, 2014; Doorman, 2022). Utrecht University's m-index of 1.286 underscores consistent scholarly output (Doorman, 2022), reflecting the global scope of IBL research.

Thematic analysis reveals recurring research focuses, including 'constructivism,' 'problem-solving,' and 'technology-enhanced learning' (Schallert et al., 2022). Lupión-Cobos et al. (2021) highlight digital tools' role in supporting remote inquiry activities, followed by Doorman (2022), who emphasizes the growing interest in real-world mathematical applications through 'mathematical modeling.' Radmehr et al. (2023) further underscore IBL's efficacy in fostering deeper mathematical reasoning. Challenges to IBL implementation persist, particularly regarding teacher preparedness. Maass et al. (2019) stress the importance of professional development to equip educators with IBL methodologies. Additionally, digital inequalities hinder adoption, with Saritas (2022) identifying technology access disparities as a barrier. Zakaria et al. (2023) advocate for targeted interventions, such as digital infrastructure improvements and teacher training.

This analysis highlights IBL's potential to reshape mathematics education through digital integration and student-centered learning. Huang et al. (2021) recommend comparative studies on IBL implementations to identify best practices across cultural settings. Building on this, Gomez-Chacon et al. (2024) emphasize the need for future research to investigate the longitudinal impacts of IBL frameworks and their adaptability across diverse educational contexts. Together, these insights highlight IBL's potential to reshape mathematics education through digital integration and student-centered learning, refining methodologies to enhance mathematical understanding and engagement.

In conclusion, this bibliometric analysis provides a comprehensive overview of Inquiry Based Learning (IBL) in mathematics education, highlighting the field's steady growth, key contributors, and thematic developments. The significant contributions from countries such as the United States, Australia, and the Netherlands, alongside prominent institutions like the University of California and Utrecht University, underscore the global research commitment to advancing IBL practices. Core themes such as constructivism, problem-solving, and technology-enhanced learning emphasize IBL's pedagogical versatility in promoting deep mathematical understanding and inquiry-driven learning experiences. Despite its focal areas, the study identifies challenges such as teacher preparedness, digital inequalities, and the need for professional development to support effective IBL implementation. Addressing these barriers requires targeted policy initiatives, including investments in teacher training, digital infrastructure, and curricular alignment, to maximize the potential of IBL in mathematics

education. Looking ahead, future research should explore the longitudinal impacts of IBL frameworks, investigate cross-cultural implementations, and analyze digital tool integrations to enhance inquiry-based methodologies. By fostering international collaboration and addressing implementation challenges, IBL can continue to transform mathematics education, promoting critical thinking, collaborative learning, and real-world problem-solving skills for students globally.

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