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Unveiling Inquiry: A Collaborative Two Decade Bibliometric Analysis of Science Learning and Investigation

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ABSTRACT: This bibliometric analysis, titled "Unveiling Inquiry: A Collaborative Two Decade Bibliometric Analysis of Science Learning and Investigation," explores the evolution and impact of research in science learning and investigation from 2000 to 2024. The study addresses the growing need to understand how educational methodologies and inquiry-based learning (IBL) have developed over the years, reflecting their significance in shaping modern educational practices. Utilizing data retrieved from the Scopus database and analysed using VOSviewer, this research systematically examines a dataset comprising 1,239 publications. The analysis focuses on identifying trends, key contributors, as well as influential publications within the field. The results reveal a significant upward trend in the number of publications, particularly between 2010 and 2018, indicating heightened research activity likely driven by advancements in educational technologies and pedagogical strategies. Journal articles dominate the publication types, accounting for 73.7% of the total, underscoring the academic community's preference for peer-reviewed dissemination. Conference papers, making up 26.3%, highlight the importance of rapid idea exchange and emerging research. Key journals, comprising the Journal of Research in Science Teaching and the International Journal of Science Education, serve a pivotal role in sharing research findings. The variation in publication trends from other sources illustrates the dynamic nature of the field. The analysis further emphasizes the contributions of prolific authors, highlighting the field's collaborative and interdisciplinary nature. Overall, the study affirms the strong and growing interest in science learning and investigation, demonstrating its significant impact on the development of educational theories and practices over the past two decades.

INTRODUCTION

The landscape of educational methodologies has seen a significant shift towards collaborative inquiry-based learning (IBL), which emphasizes the active participation of students in the learning process. This approach not only promotes a deeper comprehension of scientific processes but also boosts students' motivation and engagement with the subject matter (Bell et al., 2010). Collaborative inquiry learning involves students engaging in self-regulated learning activities, often supported by teachers, to perform steps of inquiry similar to those undertaken by scientists. This method has been shown to cultivate critical thinking and problem-solving skills, which are crucial for engaging with complex and open-ended knowledge objects (Muukkonen & Lakkala, 2009). The integration of collaborative inquiry

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in educational settings is seen as a promising avenue for advancing both individual and collective learning outcomes. Bibliometric analysis has emerged as a valuable tool for mapping the research landscape and uncovering trends in collaborative IBL. Studies have utilized bibliometric methods to systematically review the literature, revealing the growing interest and diverse applications of this educational approach (Şen, 2023; Dewi et al., 2021). For instance, the analysis of publications related to process-oriented guided inquiry learning (POGIL) has highlighted the widespread adoption of this method across various research areas and its significant impact on student engagement and learning outcomes (Şen, 2023).

Similarly, web-based inquiry has been identified as a crucial medium for supporting science education, especially during the pandemic, by facilitating the broad sharing and integration of knowledge (Dewi et al., 2021). These bibliometric studies offer valuable insights into the evolution of collaborative IBL and highlight the importance of ongoing research and development in this field to improve educational practices and outcomes.

LITERATURE REVIEW

The exploration of inquiry-based learning (IBL) in science education has been a central focus of research throughout the past two decades, revealing significant trends and insights into its implementation and impact. A consistent theme across multiple studies is the potential of IBL to enhance students' engagement and interest in STEM fields. (Ribeirinha et al., 2024) highlight the effectiveness of inquiry-based practices in enhancing female students' interest in STEM careers, underscoring the role of such pedagogies in advancing gender equity in science education. Similarly, (Huang & Pei, 2024) demonstrates the efficacy of web-based inquiry in developing science identity among elementary students, suggesting that digital platforms can complement traditional inquiry methods. These findings underscore the adaptability of IBL across different educational contexts and its capacity to address gender disparities and identity formation in STEM education.

Despite the promising outcomes associated with IBL, several studies point to challenges and limitations in its application. (Chi et al., 2024) highlights a negative correlation between the frequency of inquiry-based activities as well as science achievement, although this relationship is positively moderated by teacher support. This suggests that while IBL can be beneficial, its success is contingent upon adequate teacher facilitation and support. (Meng & Jumaat, 2024) further corroborate this by showing that online IBL significantly impacts students' engagement and performance, yet the effectiveness of such interventions may vary based on the level of teacher involvement and the educational setting. These studies highlight the critical role of teacher support and the need for professional development to optimize the implementation of IBL strategies.

The integration of technology in IBL has emerged as a significant trend, with several studies exploring its potential to enhance learning outcomes. (Ahmed et al., 2024) discusses the use of cloud-based science labs to facilitate authentic science inquiry, revealing the importance of standardized and modularized digital tools in supporting IBL at scale. (Singh-Pillay, 2024) advocates for simulation-based learning in contexts lacking traditional laboratory resources, illustrating how technology can bridge gaps in resource-constrained environments. These past studies as a whole emphasize the transformative potential of technology in expanding the reach and effectiveness of IBL, particularly in under-resourced settings.

However, the literature also identifies gaps and areas for further research. (Wan et al., 2024) highlight the inconsistent effects of inquiry on science achievement, emphasizing the importance of a deeper understanding of the different aspects of inquiry and their distinct impacts. This points to a need for more comprehensive studies that dissect the components of IBL and their interactions with various educational variables. Additionally, (Čiháková, 2024) notes the underutilization of outdoor teaching in conjunction with IBL, suggesting that future research could explore the synergies between these approaches to enhance scientific literacy. IBL holds significant promise for improving science education, its implementation is fraught with challenges that necessitate further investigation. The existing body of research emphasizes the importance of teacher support, the integration of technology and the investigation of diverse inquiry modalities in optimizing the effectiveness of IBL. Future research should aim to address these gaps, providing clearer guidelines and strategies for educators to effectively harness the potential of IBL in diverse educational contexts.

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RESEARCH QUESTION

This paper presents a bibliometric analysis by focusing on inquiry-based learning (IBL) and scientific investigation of six main research questions (RQs):

1. What type of documents are used for the subject of research?
2. What are the research trends of inquiry in science learning and investigation according to the year of publication?
3. Which are the most influential journals about research?
4. Who are the most productive authors about research?
5. What are the popular keywords related to the study?
6. What are co-authorship countries' collaboration?

METHODOLOGY

Bibliometrics entails the collection, organization and analysis of bibliographic data derived from scientific publications (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). This includes basic descriptive statistics, for instance, the journals where articles are published, the year of publication and the classification of main authors (Wu & Wu, 2017). It also encompasses more advanced methods, for instance, document co-citation analysis. Conducting a successful literature review (LR) requires an iterative process of identifying the right keywords, searching the literature and performing a detailed analysis to create a comprehensive bibliography and achieve reliable results (Fahimnia et al., 2015). With this in mind, the research aimed to concentrate on high-quality publications, as they offer important perspectives on the theories shaping the growth of the research field. To guarantee data reliability, the study utilized the SCOPUS database for data collection (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017. Additionally, to ensure the quality of the publications included, only documents from rigorously peer-reviewed academic journals and conference papers were considered, whereas books, book chapters, lecture notes, reviews and editorial materials were deliberately excluded (Gu et al., 2019). Using Elsevier's Scopus renowned for its comprehensive coverage, this study retrieved a total of 1,239 journal articles and conference papers published between 2000 and 2024 for further analysis. After screening, eligibility assessment and data cleaning, 946 documents were retained for the final bibliometric and visualisation analyses. The term 'two decades' is used to denote a long-term bibliometric span covering approximately twenty-four years of publication trends.

The tables outline the methodology used for a bibliometric search on the inquiry in science learning and investigation using the Scopus database. Table 1 displays the search string, whereas Table 2 outlines the selection criteria. This approach ensures a focused and relevant dataset for analysing trends and developments in inquiry learning and scientific investigation.

Table 1. The search strings

Scopus	TITLE-ABS-KEY ((inquiry) AND (learning) AND (science) AND (investigation OR experiment OR practice) AND (school)) AND (LIMIT-TO (LANGUAGE, "English")) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE , "cp"))

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Table 2. The selection criterion in searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2000 – 2024	<2000 and > 2024
Literature type	Journal (Article), Conference paper	Book chapter, Review, Book, Conference review, Note, Erratum, Editorial

This refinement ensures consistency between the documented analysis window (2000–2024) and the Scopus query parameters, addressing any potential discrepancy noted by the reviewer. Only peer-reviewed journal articles and conference papers were included, while books, book chapters, reviews, editorials, conference reviews, errata and lecture notes were excluded to maintain the quality and integrity of the dataset. The inclusion and exclusion criteria applied are summarised as follows: publications must be in English, fall within the years 2000–2024 and be categorised as journal articles or conference papers; publications outside this year range or belonging to non-peer-reviewed or non-indexed categories were excluded.

To enhance transparency in the selection process, a PRISMA-style screening flow was applied. The initial Scopus search identified 1,239 records. Following automatic deduplication, 42 duplicates were removed, leaving 1,197 unique records for title and abstract screening. At this stage, 214 records were excluded for being off-topic or unrelated to school-based inquiry, science learning, or scientific investigation. The remaining 983 records underwent full-text eligibility assessment, during which 37 records were removed due to incomplete metadata, such as missing author keywords, missing affiliations, or unindexed abstracts. The final dataset included 946 documents, which formed the basis of all bibliometric and visualisation analyses in this study. The overall screening process is illustrated in Figure 1, which presents the PRISMA-style flow diagram.

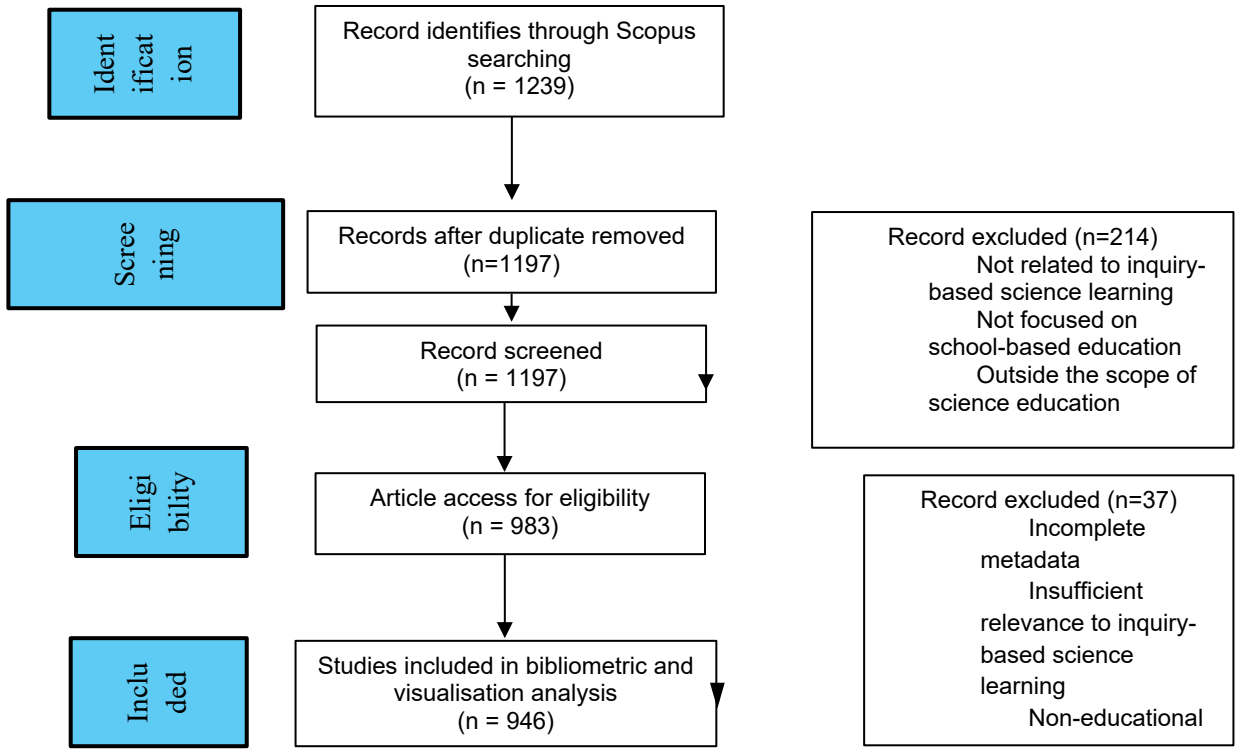

Figure 1. PRISMA-style flow diagram of the bibliometric screening and selection process Source: Page et al. (2021)

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The bibliographic fields exported from Scopus included authors' names, affiliations, country of the corresponding author, document titles, abstracts, author keywords, indexed keywords, source titles (journals), publication years, citation counts, reference lists and funding information (where available). Prior to analysis, several data cleaning procedures were performed. These included author name disambiguation (e.g., merging variations of the same author), harmonisation of keyword synonyms (such as consolidating "inquiry-based learning", "inquiry learning" and "IBL"), unification of country names and removal of single-occurrence or irrelevant keywords that could fragment the network structure. These steps ensured dataset accuracy and improved the validity of network visualisations.

Bibliometric analysis was conducted using the full counting method, in which each author, country and keyword receives full credit for each document. Association Strength (AS_{ij}) was applied as the normalisation method for all co-occurrence and collaboration networks to provide balanced weightings between items. Analytical thresholds were defined to enhance the interpretability of the resulting maps: a minimum of 10 occurrences for keywords, at least 5 publications for authors and at least 5 publications for countries. Clustering followed VOSviewer's default settings, including a resolution of 1.0 and a minimum cluster size of five items. Network, overlay and density visualisations were generated using VOSviewer version 1.6.19, while descriptive statistics, trend graphs and top-10 tables were prepared using Microsoft Excel 365 and Scopus Analyzer.

This study complies with Scopus data usage terms and no human participants were involved. Limitations associated with database-driven studies are acknowledged, including English-language indexing bias, database coverage bias, threshold sensitivity in VOSviewer and the potential for residual keyword synonymy despite harmonisation efforts. These considerations are important for contextualising the interpretation of results and for guiding future bibliometric research.

RESULT AND DISCUSSION

What are the research trends of inquiry in science learning and investigation according to the year of publication?

The figure illustrates the annual growth of publications indexed in Scopus over the study period, highlighting phases of gradual development, accelerated growth and subsequent stabilisation in research output.

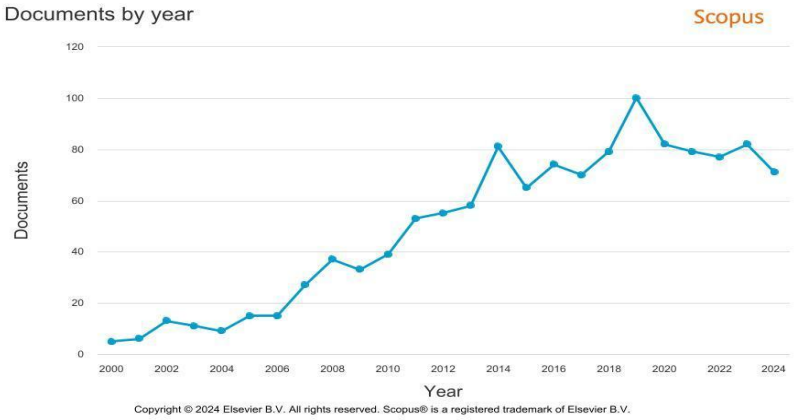

Figure 2. Annual publication trends in inquiry-based science learning and investigation research (2000–2024).

The bibliometric analysis of publications from 2000 to 2024 reveals a significant upward trend in the field of science learning and investigation. Initially, the number of documents published annually was relatively low, with a gradual increase observed from 2000 to 2010. This period represents the foundational growth phase, likely fueled by the rising recognition of the significance of science education and IBL. The consistent increase in publications over the decade indicates a heightened interest and sustained investment in research focused on science learning methodologies and their influence on educational outcomes. From 2010 onwards, the trend became more pronounced, with notable peaks

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around 2014 and 2018, indicating periods of heightened research activity. This surge could be attributed to advancements in educational technologies and pedagogical strategies that have spurred further investigation and discourse. However, post-2018, there is a slight decline and stabilization in publication numbers, which may reflect a maturation of the field or shifts in research focus. Overall, the data underscores a robust and evolving interest in science learning and investigation, highlighting its critical role in shaping educational practices over the past two decades.

What type of documents are used for the subject of research?

Figure 3 illustrates the distribution of document types in the field, showing that journal articles constitute the majority of publications, followed by conference papers.

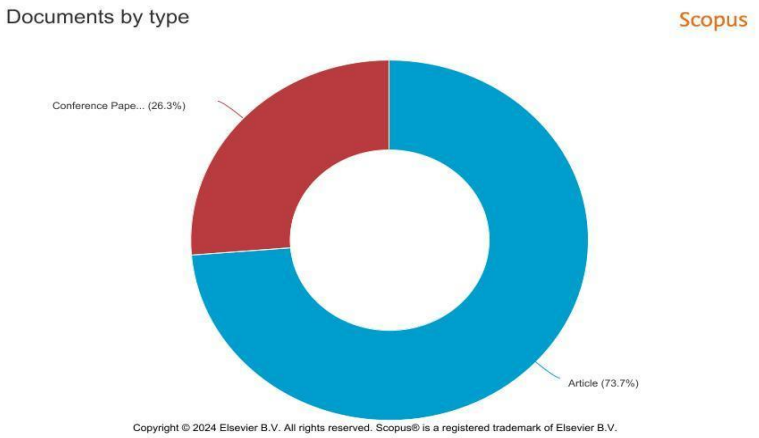

Figure 3. Distribution of document types in inquiry-based science learning and investigation research (2000–2024).

The analysis of document types in the field of science learning and investigation reveals a predominant reliance on journal articles, which constitute 73.7% of the total publications. This indicates a strong preference for disseminating research findings through peer-reviewed journals, reflecting the academic community's emphasis on rigorous validation and widespread accessibility. Journal articles are often seen as the gold standard for scholarly communication, providing comprehensive insights and detailed methodologies that contribute to the field's knowledge base. This preference underscores the importance of thorough, peer-reviewed research in advancing educational theories and practices.

Conversely, conference papers account for 26.3% of the documents, highlighting their role in facilitating the rapid exchange of ideas and emerging research. Conferences provide an important platform for researchers to share initial findings, participate in academic discussions and receive immediate feedback from peers, which is crucial for refining research approaches and methodologies. The significant proportion of conference papers suggests an active and dynamic research community that values collaboration and the sharing of innovative approaches. Together, these document types illustrate a balanced approach to scholarly communication, combining the depth of journal articles with the immediacy and interactivity of conference presentations.

Which are the most influential journals about research?

The figure presents publication trends of key source journals over time, indicating journals that play a central role in disseminating research on inquiry-based learning and science education.

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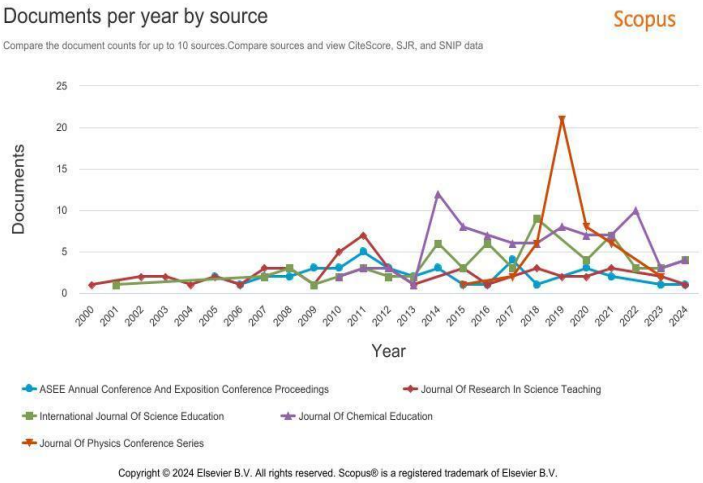

Figure 4. Distribution of publications across major journals in inquiry-based science learning and investigation research (2000–2024).

The analysis of document sources over the years highlights the diverse contributions of various journals and conference proceedings to the field of science learning and investigation. The "Journal of Research in Science Teaching" and the "International Journal of Science Education" consistently contribute a steady number of publications, indicating their central role in disseminating research findings. These journals are likely influential due to their focus on educational methodologies and their impact on science teaching practices. The steady output from these sources suggests a sustained interest and ongoing research in these areas, reflecting their importance in the academic community.

In contrast, the "Journal of Chemical Education" and the "Journal of Physics Conference Series" show more variability in their publication trends, with notable peaks in certain years. This variability might be attributed to specific thematic issues or conferences that align with emerging trends or breakthroughs in science education. The ASEE Annual Conference and Exposition Conference Proceedings also have an important role, particularly in fostering discussions and promoting the exchange of innovative ideas. The peaks and troughs in these sources highlight the dynamic nature of research dissemination, where certain topics gain prominence at different times, driven by technological advancements or shifts in educational priorities. Overall, the data underscores the collaborative and multifaceted nature of research in science learning and investigation.

Who are the most productive authors about research?

The figure displays authors with the highest number of publications based on the final dataset (N = 946), reflecting sustained research contributions and collaborative engagement within the field.

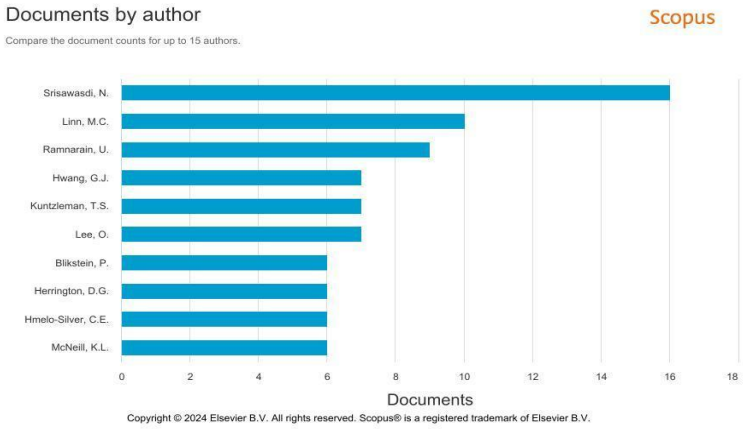

Figure 5. Productivity of leading authors in inquiry-based science learning and investigation research (2000–2024).

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The bibliometric analysis of authorship in science learning and research highlights the contributions of several key researchers. Notably, Srisawasdi, N. stands out as the most prolific author, with 16 publications, representing 1.294% of the total output. This indicates a significant impact on the field, likely through extensive research and collaboration. Following Srisawasdi, M.C. Linn and U. Ramnarain also contribute substantially, with 10 and 9 documents respectively. Their work likely spans various aspects of science education, reflecting diverse research interests and methodologies that enrich the academic discourse.

Other notable contributors include G.J. Hwang, T.S. Kuntzleman and O. Lee, each with 7 documents and several authors with 6 documents, such as P. Blikstein and C.E. Hmelo-Silver. This distribution suggests a collaborative and interdisciplinary approach, with multiple researchers contributing to the advancement of science learning and investigation. The presence of these authors underscores the importance of sustained research efforts and the sharing of innovative ideas, which collectively drive the field forward. The diversity in authorship also reflects the global and multifaceted character of research in this field, fostering a rich exchange of knowledge and practices. Table 3 shows the details about the most productive authors.

Table 3. Top 10 most productive authors in inquiry-based science learning research

Author name	Number of documents	Percentage (%)
Srisawasdi, N.	16	1.294
Linn, M.C.	10	0.809
Ramnarain, U.	9	0.728
Hwang, G.J.	7	0.566
Kuntzleman, T.S.	7	0.566
Lee, O.	7	0.566
Blikstein, P.	6	0.485
Herrington, D.G.	6	0.485
Hmelo-Silver, C.E.	6	0.485
McNeill, K.L.	6	0.485

What are the popular keywords visualisation mapping related to the study?

The network was generated using VOSviewer version 1.6.19 based on author keywords. A minimum threshold of 10 occurrences was applied, resulting in 127 keywords included in the analysis. The full counting method and association strength normalisation were used. Node size represents keyword frequency, link thickness indicates co-occurrence strength and colours denote thematic clusters.

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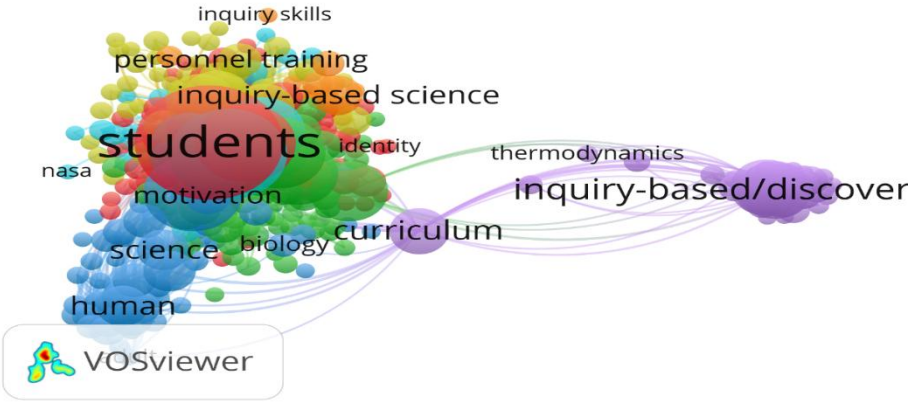

Figure 6. Network visualisation of keyword co-occurrence in inquiry-based science learning and investigation research (2000–2024).

The bibliometric analysis of keywords associated with science learning and investigation uncovers key trends and focal areas that have shaped educational research over the past two decades. The keyword "inquiry-based learning" stands out with the highest occurrences (133) and a substantial total link strength (618), showing its central role in the discourse surrounding science education. This prominence suggests a strong emphasis on pedagogical approaches that encourage students to engage actively with scientific concepts through exploration and questioning. The high link strength further implies that IBL is well-integrated with other key concepts, reflecting its importance in fostering a deeper understanding of science among learners.

Another prominent keyword is “education,” appearing 129 times with a total link strength of 970, highlighting the broad and foundational role of educational research within this field. The extensive link strength suggests that education serves as a pivotal node connecting various subfields and methodologies, highlighting its integral role in shaping the landscape of science learning and investigation. This interconnectedness points to a multidisciplinary approach, where educational strategies are continuously evolving to incorporate new insights and technologies, thereby enhancing the effectiveness of science teaching and learning.

Additionally, the keyword "collaborative learning" with 16 occurrences and a link strength of 67, along with "collaborative/cooperative learning" (15 occurrences, 82 link strength), emphasizes the growing recognition of collaborative approaches in science education. These keywords reflect a shift towards learning environments that prioritize interaction and cooperation among students, fostering a community of learners who can collectively construct knowledge. The moderate link strengths suggest that while collaborative learning is gaining traction, there is still room for further integration and exploration within the broader context of science education research. This trend aligns with contemporary educational theories that advocate for social constructivism and the benefits of peer-to-peer learning in enhancing student engagement and understanding.

What are co-authorship countries’ collaboration?

Countries with a minimum of 5 publications were included in the analysis. The network was constructed using the full counting method with association strength normalisation. Node size reflects publication output, link thickness represents collaboration intensity and colours indicate clusters of international research collaboration.

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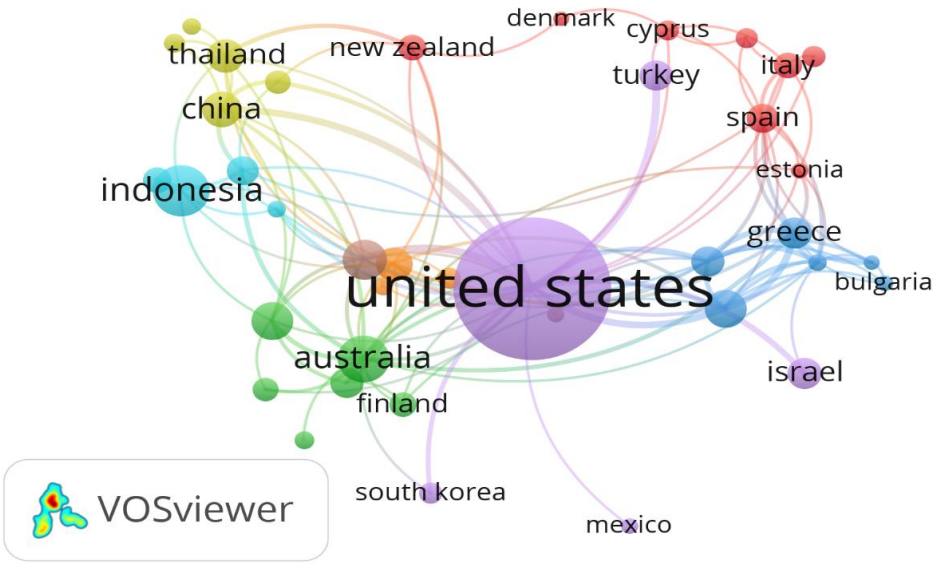

Figure 7. International co-authorship network in inquiry-based science learning and investigation research (2000–2024).

The bibliometric analysis of co-authorship across countries in the field of science learning and investigation underscores the global scope of research collaboration. The United States emerges as a leading contributor, with 557 documents and a staggering 15,679 citations, reflecting its central role in advancing educational research. The high total link strength of 69 indicates robust international collaborations, suggesting that U.S. researchers frequently partner with colleagues worldwide to explore and innovate in science education. This extensive network of collaboration underscores the importance of cross-border partnerships in addressing complex educational challenges and sharing diverse perspectives and methodologies.

Australia and Germany also emerge as notable contributors, with 61 and 41 publications respectively, accompanied by substantial citation counts (772 for Australia and 566 for Germany). Their total link strengths of 27 and 28 further emphasize their active engagement in international research networks. These countries' involvement in collaborative research efforts highlights their commitment to advancing science education through shared knowledge and resources. The presence of countries like the Netherlands and Greece, with notable link strengths of 26 and 29, respectively, indicates their strategic partnerships and contributions to the global discourse on science learning and investigation.

Interestingly, smaller countries such as Singapore and Israel, despite having fewer documents (24 and 28, respectively), show high citation counts and link strengths, particularly Israel with 1,183 citations. This suggests that their research outputs are highly impactful and well-integrated into the global research community. The data reveals a varied and interconnected research landscape in which countries of varying sizes and research capacities contribute to the collective understanding of science education. This interconnectedness is crucial for fostering innovation and ensuring that educational practices are informed by a wide array of cultural and contextual insights, ultimately enhancing the quality and effectiveness of science learning worldwide.

CONCLUSION

The bibliometric analysis of publications from 2000 to 2024 in the field of science learning and investigation reveals a dynamic and evolving landscape. Initially, the number of publications was relatively modest; however, a gradual increase from 2000 to 2010 signifies a foundational growth phase, likely spurred by the increasing recognition of the importance of science education and IBL. This period reflects a rising interest and investment in research exploring science learning methodologies and their influence on educational outcomes. From 2010 onwards, the trend became more pronounced, with notable peaks around 2014 and 2018, suggesting periods of heightened research activity possibly

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spurred by advancements in educational technologies and pedagogical strategies. However, post-2018, a slight decline and stabilization in publication numbers may indicate a maturation of the field or shifts in research focus. Overall, the data underscores a robust and evolving interest in science learning and investigation, highlighting its critical role in shaping educational practices over the past two decades. The analysis of document types and sources further illustrates the scholarly communication landscape in this field. Journal articles, constituting 73.7% of the total publications, highlight a strong preference for peer-reviewed dissemination, reflecting the academic community's emphasis on rigorous validation and accessibility. Conversely, conference papers, comprising 26.3% of the total, play a crucial role in facilitating the swift exchange of ideas and the dissemination of emerging research. The diverse contributions from various journals and conference proceedings, such as the "Journal of Research in Science Teaching" and the "International Journal of Science Education," underscore their central role in disseminating research findings. The variability in publication trends from sources like the "Journal of Chemical Education" and the "Journal of Physics Conference Series" highlights the dynamic nature of research dissemination, driven by technological advancements or shifts in educational priorities. The collaborative and multifaceted nature of research in science learning and investigation is further emphasized by the diverse authorship, with key contributors significantly impacting the field through extensive research and collaboration. This diversity fosters a rich exchange of knowledge and practices, driving the field forward.

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DECLARATION OF GENARATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author used ChatGPT (version 5.2) to assist in improving the clarity, coherence and academic tone of the writing. All content generated or refined using this tool was carefully reviewed, edited and validated by the author, who takes full responsibility for the accuracy, originality and integrity of the final manuscript.

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