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# Mapping the Landscape of Reflective Practice in Inquiry Based Physics Education: A Bibliometric Analysis

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**ABSTRACT**

Reflective practice is widely recognized as a critical component of inquiry-based learning; however, its integration within inquiry-based physics education (IBPE) remains fragmented and insufficiently synthesized. This study aims to systematically map the scholarly landscape of reflective practice in IBPE by analyzing publication trends, influential contributors, collaboration patterns, and dominant thematic structures. A bibliometric research design was employed using data retrieved from the Scopus database. Journal articles published between 2015 and 2025 were identified through a structured search strategy and screened using predefined inclusion criteria. After data cleaning and refinement, 916 documents were included in the analysis. Bibliometric analyses were conducted using Biblioshiny (R-bibliometrix) and VOSviewer to generate descriptive statistics, citation networks, keyword co-occurrence maps, thematic evolution, and collaboration visualizations. The results indicate a steady increase in research output, with an annual growth rate of 9.88%, reflecting growing scholarly attention to the reflection–inquiry nexus in physics education. The field is characterized by strong collaboration networks and is concentrated within a limited number of core journals and institutions, predominantly led by researchers from Western countries. Thematic findings show that reflective practice is largely framed through human-centered, qualitative, and teacher-focused perspectives, while physics-specific epistemic practices such as modeling and uncertainty analysis remain underrepresented. This study contributes a focused bibliometric mapping of reflective practice in IBPE and identifies research gaps to guide future integration of reflective processes into authentic physics inquiry.

## INTRODUCTION

Inquiry aspires to cultivate scientifically literate learners who reason with evidence, design investigations, and reflect on their thinking and progress habits of mind long argued to be central to "doing science" (Wiyarsi et al., 2021; Angkur, 2025). In this vision, reflective practice is not an add-on but the engine that helps students and teachers interrogate assumptions, refine questions, and make sense of discrepant results, thereby amplifying the cognitive gains typically associated with inquiry (e.g., critical thinking, transfer, and metacognition). Contemporary syntheses in science education and teacher education suggest that when inquiry is coupled with structured reflection, learners' higher-order outcomes improve and teachers' professional judgment deepens, aligning with 21st-century competency frameworks (Handayani et al., 2018; Omra et al., 2025).

Yet the everyday reality in many physics classrooms looks different. Inquiry tasks are frequently implemented as procedural labs, and "reflection" is reduced to brief lab-report conclusions or checklists that do not reach analysis of strategy quality, uncertainty, or conceptual change (Riaz et al., 2019; Sypsas et al., 2020; Siantuba et al., 2023; Pols & Dekkers, 2024; Karen et al., 2024). Recent classroom and teacher-development studies describe persistent tensions: time pressure, assess-ment regimes that privilege correct answers over sense-making, and limited scaffolds for reflection in the midst of experimentation. As a result, reflective moves (e.g., revisiting models, articulating reasoning limits) are sporadic, and inquiry often

under-delivers on its metacognitive promise in physics contexts (Willis et al., 2021; Acharya et al., 2024; Yan et al., 2025; Emden et al., 2025).

This disconnect produces concrete problems. For students, under-scaffolded reflection during inquiry can blunt gains in scientific reasoning and collaborative argumentation; for teachers, the absence of systematic reflective routines makes it harder to notice student thinking, adjust investigations in real time, and transfer insights across topics (Thompson et al., 2019; Gutierez, 2021; Orozco et al., 2023; Koes Handayanto et al., 2024). Evidence from inquiry-lab research shows that, without explicit structures for reflective cycles, teamwork, problem-solving, and attitudes may stagnate despite hands-on activity especially in complex physics investigations where measurement, modeling, and uncertainty analysis are central (Fakhriyah et al., 2023).

Critically, there is a knowledge gap between the field's aspirations and what we systematically know about reflective practice within inquiry-based physics education (Brown et al., 2021; Schaepkens & Lijster, 2023; Phua et al., 2024). While recent reviews and meta-analyses affirm inquiry's positive effects on higher-order outcomes, they rarely disaggregate the "reflective mechanisms" embedded in those interventions or map which reflective tools (learning journals, prompts, video reflection, peer feedback) are actually used in physics education versus other sciences (Lerchenfeldt et al., 2019; Lim et al., 2022; Sudirman et al., 2024). Nor do we have a consolidated view of influential authors, outlets, collaboration networks, or thematic clusters (e.g., uncertainty analysis, model-based inquiry, computational notebooks) specific to reflective practice in IBPE (Stratmann et al., 2024; Arifin et al., 2025).

Despite growing scholarship on inquiry and reflection separately, there remains a lack of systematic mapping that specifically examines how reflective practice is conceptualized, operationalized, and integrated within inquiry-based physics education. Existing reviews tend to address inquiry in general science contexts or reflective practice in teacher education broadly, leaving the reflection–inquiry nexus in physics education insufficiently synthesized. This gap limits our understanding of dominant research trends, influential contributors, collaboration patterns, and underexplored thematic areas unique to IBPE.

A bibliometric solution is timely. Bibliometric techniques when aligned with transparent screening such as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and science-mapping tools can chart the intellectual structure of a domain, reveal co-authorship and co-citation communities, and trace the evolution of key themes. Recent education-research exemplars demonstrate how bibliometric mapping identifies hotspots, methodological shifts, and under-explored intersections; these methods are well-suited to surface where "reflection" is operationalized within inquiry studies in physics and how that differs from adjacent domains (Page et al., 2021; Patty et al., 2024).

The strengths of a bibliometric approach for this topic are threefold. First, it aggregates dispersed scholarship across physics education and teacher education to reveal patterns invisible to narrative reviews for example, keyword co-occurrence linking "error analysis," "metacognition," and "argumentation. Second, it supports comparative insights across phases (pre-service, in-service, undergraduate labs) and settings (school physics vs. introductory university physics). Third, it produces reproducible maps that stakeholders can use to design reflective-inquiry PD and curricula grounded in the field's actual knowledge structure (Patty et al., 2024; Stanton, 2021).

There are also limitations to acknowledge. Bibliometric analyses depend on database coverage, indexing practices, and keyword choices; physics-education work on reflection may be hidden under labels like "self-explanation," "notebooking," or "model revision." Moreover, bibliometrics privileges what is published and citable, potentially underrepresenting classroom innovations and local languages. These constraints argue for rigorous inclusion criteria, sensitivity analyses, and complementary reading of full texts after mapping to avoid over-interpreting network visualizations (Admoko et al., 2022; Korkmaz & Toraman, 2024; Abu, 2023).

Against this backdrop, the present article "Mapping the Landscape of Reflective Practice in Inquiry-Based Physics Education: A Bibliometric Analysis" pursues two aims: (1) to systematically map the scholarly landscape on reflective practice within inquiry (authors, outlets, nations, collaboration and co-citation networks; thematic clusters and trends), and (2) to identify actionable research and practice opportunities (e.g., reflective tools most associated with learning gains; under-studied topics such as reflection on uncertainty and modeling). The study's novelty lies in its exclusive focus on the reflection–inquiry nexus within physics education (not general science), its use of a transparent PRISMA-aligned workflow, and its comparative lens across teacher-education and classroom implementations to spotlight where reflective practice most powerfully augments inquiry in physics.

## RESEARCH METHOD

This study employed a bibliometric design to systematically map the trends and intellectual structure of research related to reflective practice within the context of inquiry-based physics education. The bibliometric method enables the identification of publication patterns, influential authors, institutions, and thematic evolution within a specific domain (Yaumie et al., 2025). The research followed three main stages: data collection, data processing, and bibliometric analysis.

The data source was obtained from the Scopus database due to its broad coverage and high-quality indexing of peer-reviewed literature (I.V., 2021; Darmawan & Rahmawati, 2024; Mezquita et al., 2024). The search query combined keywords such as "reflective practice" AND "inquiry" OR "physics education", filtered for journal articles published between 2015 and 2025, written in English, and categorized under the fields of education and science. The search was conducted in October 2025, yielding an initial set of 1.792 documents. After refinement (removing duplicates, non-relevant, and incomplete metadata), a total of 916 valid documents were analyzed.

Bibliographic data were exported in CSV format for compatibility with analytical tools. The data analysis utilized Biblioshiny (an R-package for bibliometric analysis) to conduct descriptive statistics, citation network analysis, keyword co-occurrence mapping, and thematic evolution visualization (Dagli et al., 2024; Ardiana et al., 2025; Prasetio et al., 2025). This was complemented by VOSviewer for graphical network visualization of author collaborations, keyword clusters, and co-citation patterns (Du et al., 2024; Guofang et al., 2024).

To enhance the transparency of the process, Figure 1 (to be drawn) illustrates the overall research flow from data collection to interpretation of results. The analytical emphasis was placed on identifying how reflective practice is integrated within inquiry-oriented pedagogy in physics learning, particularly in terms of publication growth, thematic hotspots, and research collaboration networks.

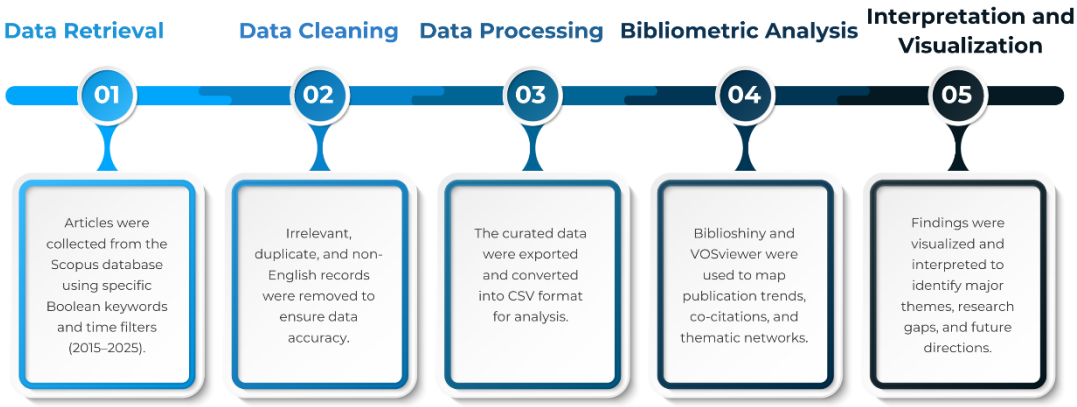



**Figure 1.** Research Flowchart (Page et al., 2021)

## RESULTS AND DISCUSSION

### Result

The bibliometric analysis covered publications on reflective practice in inquiry-based physics education from 2015 to 2025, yielding 916 documents sourced from 534 journals, books, and conference proceedings. The annual growth rate of 9.88% indicates a steady rise of scholarly attention in the past decade, reflecting growing recognition of reflection as a key component of inquiry-oriented pedagogy. The average document age of 4.04 years suggests that the field remains active and evolving, with recent studies contributing substantially to theoretical and classroom innovations.

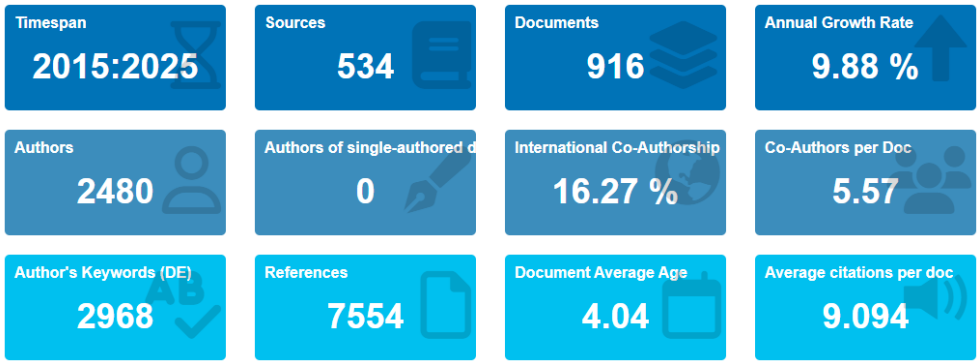



**Figure 2.** Main Information Summary of the Dataset

The dataset included 7,554 references, with an average of 9.09 citations per document, indicating a moderate yet growing citation impact. A total of 2,480 authors contributed collaboratively, as no single-authored papers were found. Each publication involved on average 5.57 co-authors, and 16.27% of the works involved international collaboration, showing the field's increasingly global nature. Moreover, journal articles (839) dominated over conference papers (77), underscoring a preference for peer-reviewed dissemination channels that ensure higher academic visibility and methodological rigor.

The publication trend from 2015 to 2025 shows a consistent and significant increase in research output related to reflective practice in inquiry-based physics education. Beginning with 62 articles in 2015, the number gradually rose to 159 in 2025, representing a strong upward trajectory that aligns with the growing global emphasis on reflective and inquiry-driven science pedagogy.

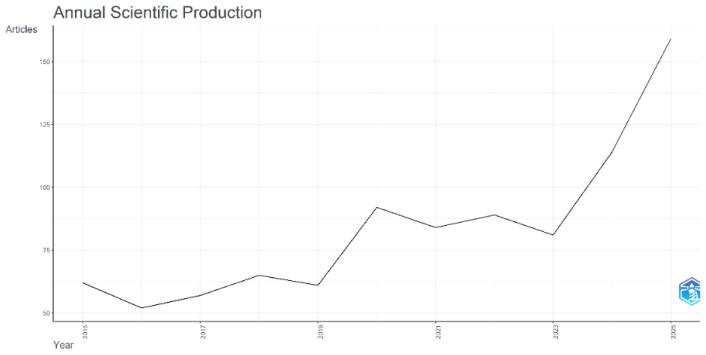



**Figure 3.** Annual Scientific Production

The sharp increase after 2020 may correspond to the surge of educational research prompted by the pandemic era, which intensified interest in reflective teaching and student-centered inquiry models. This trend highlights how reflection and inquiry have become increasingly recognized as essential competencies for both teachers and learners in contemporary physics education.

The citation trend from 2015 to 2025 reflects the evolving scholarly impact of studies on reflective practice in inquiry-based physics education. Older publications received substantially higher citations, while recent works are still accumulating recognition, indicating a typical citation-lag effect in emerging research fields.

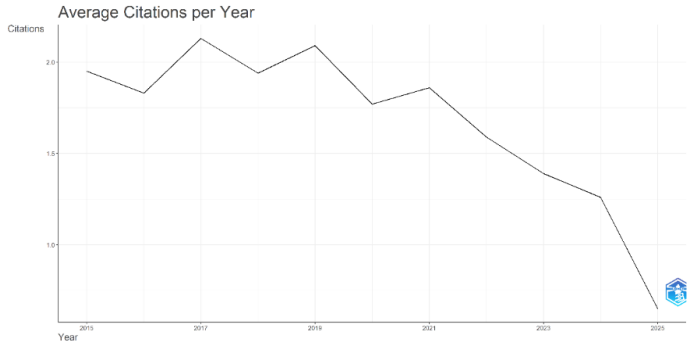



**Figure 4.** Average Citations per Year

As illustrated in Figure 5, the highest citation average occurred in 2015 (21.45 citations per article), while newer studies in 2025 have not yet gained significant citation traction (0.65 citations per article). The decline in mean citations per article corresponds to the increasing number of publications, as research volume grows faster than citation accumulation. This pattern suggests that although recent studies expand thematic diversity, their academic impact is still developing and may rise in subsequent years as reflective inquiry continues to attract wider research attention.

The three-field plot visualizes the connections between cited references (CR), authors (AU), and merged keywords (KW_Merged). It shows how specific authors are associated with key references and dominant research themes such as reflective practice, narrative inquiry, and teacher education. The color intensity and line density represent the strength of association among these three dimensions.

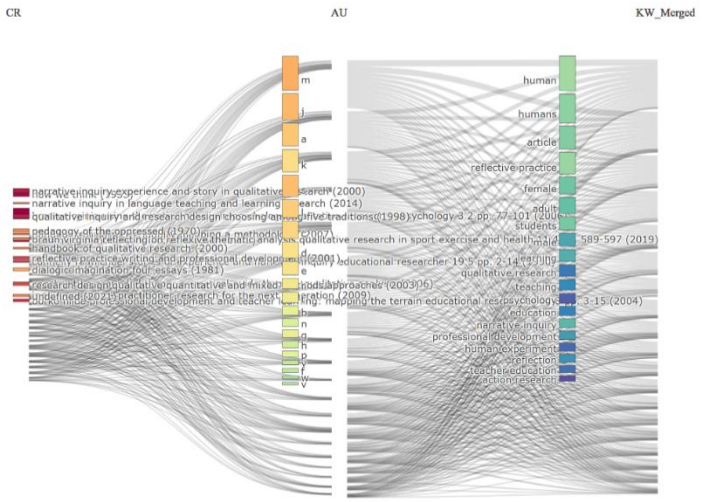



**Figure 5.** Three-Field Plot of Author–Source–Keyword Relationship

This plot highlights the most influential references and their linkage with prolific authors and major keywords in the field. The dominant themes suggest a strong focus on reflective practice and qualitative research within educational and teacher professional development contexts.

The bibliometric mapping identified the most productive and influential publication sources contributing to the topic of reflective practice in inquiry-based physics education between 2015 and 2025. A total of 534 sources were recorded, with only a few dominating the scholarly output. The concentration of papers in specific journals highlights the central publication venues shaping discourse in this research area.

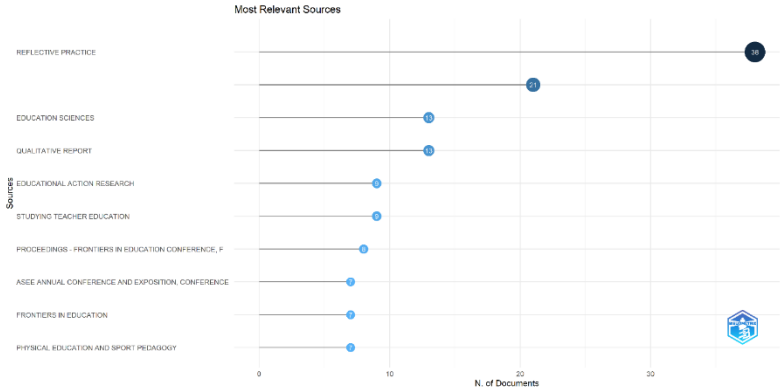



**Figure 6.** Most Relevan Source

As shown in Figure 6, the Reflective Practice journal ranks as the most prolific outlet with 38 publications, emphasizing its strong association with reflective teaching and professional learning themes. Education Sciences and The Qualitative Report follow with 13 articles each, indicating the integration of reflective frameworks within broader educational and qualitative research contexts. Meanwhile, Educational Action

Research and Studying Teacher Education each contribute 9 publications, illustrating the link between reflection, inquiry, and practitioner-based learning. Collectively, these journals represent the core intellectual platforms advancing reflective inquiry in physics education.

Figure 7 illustrates Bradford's Law of Scattering, which depicts the distribution of publications across journals within the analyzed dataset. This visualization identifies how research articles are concentrated in a few core journals while the remainder is dispersed across a broader range of less frequently cited sources.

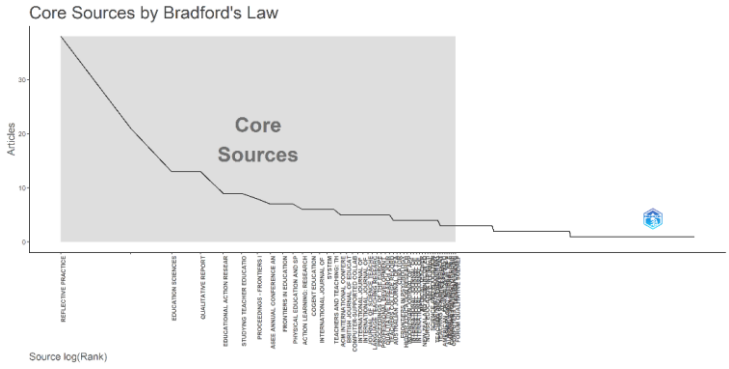



**Figure 7.** Core Sources by Bradford's Law

As shown in Figure 7, a small number of journals contribute the majority of publications in the field, indicating a strong core zone consistent with Bradford's Law. Beyond these core journals, the productivity gradually decreases across subsequent zones, reflecting a typical scattering pattern of scientific output. This distribution suggests that while a few journals serve as central outlets for research dissemination, a diverse array of peripheral journals also play a complementary role in expanding the academic discussion within the topic.

Figure 8 illustrates the local impact of publication sources based on the total citations and number of documents within the research field of reflective practice in physics inquiry learning. The visualization highlights journals that have played a central role in disseminating research findings between 2015 and 2025. Among them, Physics Education, International Journal of Science Education, and Research in Science Education stand out with the highest citation counts and document contributions, indicating their strong influence and relevance in advancing inquiry-based reflective pedagogy.

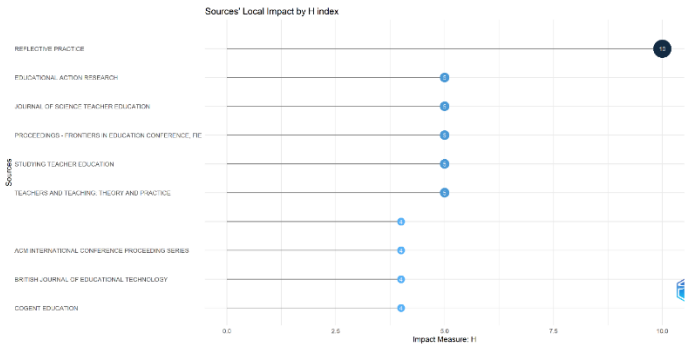



**Figure 8.** Sources' Local Impact

The figure demonstrates that citation concentration remains relatively high in a small cluster of journals, confirming their leadership in shaping theoretical and practical frameworks of reflective practice in science education. The predominance of these journals reflects both the maturity and specialization of the field, where research on reflective inquiry teaching in physics tends to converge. This finding suggests that future scholars aiming for visibility and academic impact should target these high-impact journals to ensure their work contributes meaningfully to the ongoing discourse.

Figure 9 presents the evolution of publication output across major journals contributing to reflective practice research in inquiry-based physics education from 2015 to 2025. The data reveal a notable upward trend in publication numbers, with Reflective Practice consistently dominating in productivity throughout the decade. Other journals such as Educational Action Research, Qualitative Report, and Studying Teacher

Education have also demonstrated gradual increases, indicating growing interdisciplinary engagement between reflective methodologies and inquiry pedagogy in science education.

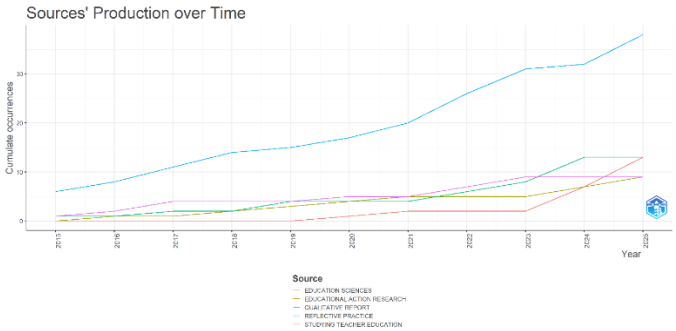



**Figure 9.** Sources' Production over Time

The continuous rise in publication output particularly the sharp increase in Reflective Practice and Education Sciences since 2020 signals a sustained expansion of interest in reflective inquiry as a professional development and instructional innovation tool. This pattern suggests that educators and researchers are increasingly recognizing the importance of self-reflection and inquiry cycles in improving physics teaching and learning outcomes. The diversification of journal outlets further implies that reflective practice is transcending disciplinary boundaries, fostering a more integrated and collaborative research landscape.

To understand the intellectual structure of research on reflective practice within inquiry-based physics education, identifying the most productive scholars is essential. Mapping the publication output of leading authors highlights who has contributed most substantially to the field over time and provides insight into dominant voices shaping theoretical and methodological development. This figure summarizes the authors with the highest number of publications in the dataset from 2015–2025.

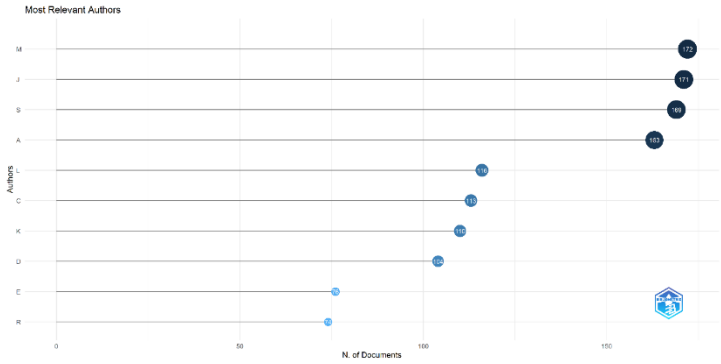



**Figure 10.** Most Relevant Authors

The visualization indicates that a small group of scholars exhibits notably high productivity, with four authors contributing between 163 and 172 documents, positioning them as central figures driving research in this domain. The next tier includes several moderately prolific authors producing between 104 and 116 publications, suggesting a broadening contributor base yet still anchored by a concentrated core of highly active researchers. This distribution reflects a pattern commonly observed in educational research networks, where a few key authors sustain long-term productivity and visibility within the field.

To gain deeper insight into the development of scholarly influence, it is important to examine how the productivity of leading authors has evolved across years. Tracking annual publication output allows us to observe patterns of consistency, growth, or decline, offering valuable context for understanding how individual researchers contribute to sustaining the field over time.

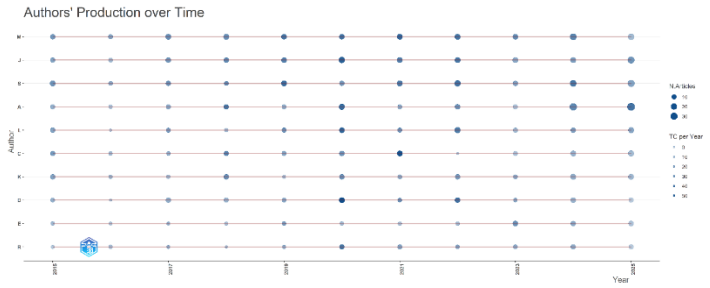



**Figure 11.** Authors' Production over Time

The visualization shows that most highly productive authors maintained steady publication activity throughout 2015–2025, with noticeable peaks around 2018–2020, where several authors reached their highest yearly output. This indicates a period of intensified research interest and collaboration within the domain. Although fluctuations occur, the overall trend reflects stable engagement from core contributors, suggesting that the field is supported by a persistent research community rather than sporadic or isolated efforts.

To further evaluate the distribution of scholarly contributions within the field, Lotka's Law was applied to assess author productivity patterns. This analysis provides insight into how publication output is concentrated among researchers and whether the field follows the typical inverse-square distribution seen in many scientific domains.

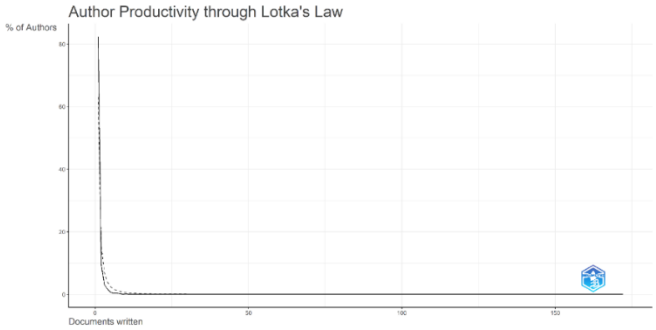



**Figure 12.** Author Productivity through Lotka's Law

The resulting curve shows a steep decline, indicating that a very small proportion of authors produce the majority of publications, while the vast majority contribute only one or two documents. This pattern strongly aligns with Lotka's expected distribution, suggesting a highly skewed authorship structure dominated by a small group of prolific researchers. Such a distribution is common in mature research areas, reflecting both specialization and sustained long-term engagement among core contributors.

To complement productivity metrics, examining authors' citation impact provides a clearer picture of their scholarly influence within the dataset. The H-index is used here as a local impact measure, capturing the balance between publication quantity and citation significance across the field's most active contributors.

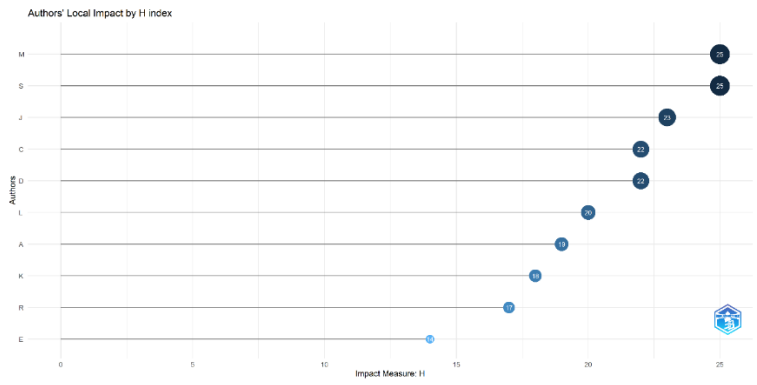



**Figure 13.** Authors' Local Impact

The figure shows that two authors achieve the highest local impact with an H-index of 25, indicating strong and consistent citation performance. Several others follow closely with H-indices ranging from 20 to 23, forming a well-defined group of influential researchers who shape the field's intellectual direction. Lower but still meaningful values appear among additional contributors, suggesting a broad but stratified impact structure, where a core cluster of authors exerts substantial influence while others contribute more modestly.

Institutional analysis provides additional perspective on how research activity is distributed across organizations contributing to the field. Identifying the most relevant affiliations highlights which universities or research institutes serve as key hubs in advancing inquiry-related reflective practice studies.

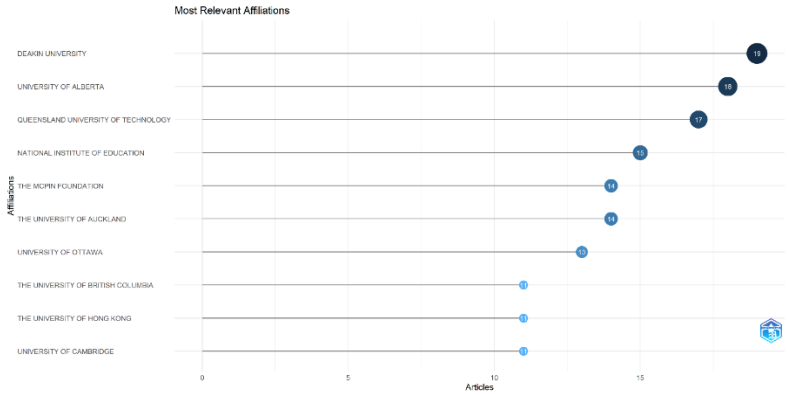



**Figure 14.** Most Relevant Affiliations

The visualization shows that Deakin University emerges as the most influential institution with 19 publications, closely followed by the University of Alberta (18) and the Queensland University of Technology (17). Several other institutions including the National Institute of Education and The McPin Foundation also contribute substantially with 14–15 documents, indicating a diverse but strong international research presence. Meanwhile, universities such as Ottawa, British Columbia, Hong Kong, and Cambridge exhibit moderate yet meaningful engagement. Overall, this pattern reflects a globally distributed research landscape led by a concentrated group of highly productive academic institutions.

To examine how institutional engagement in inquiry-related reflective practice research has evolved across the decade, the annual publication output of the most active affiliations was tracked. This helps reveal long-term trends, emerging research hubs, and periods of intensified scholarly activity within leading institutions.

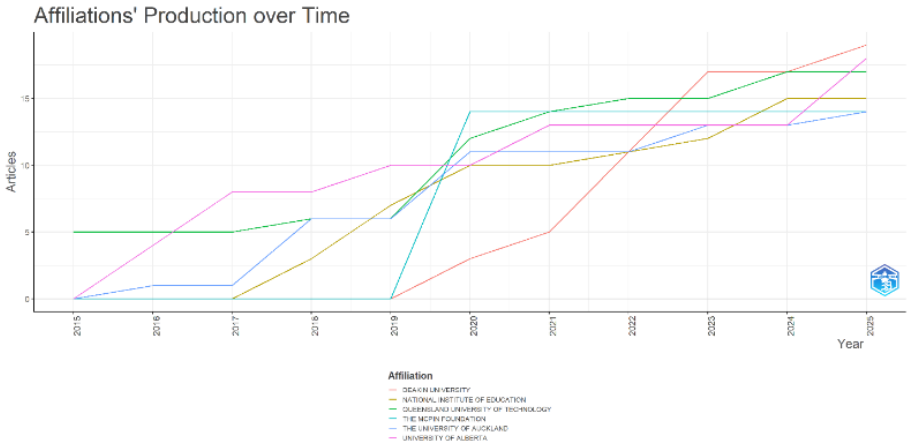



**Figure 15.** Affiliations' Production over Time

The visualization shows a steady upward trajectory for nearly all top institutions, with particularly strong growth after 2019, where universities such as Deakin, Queensland University of Technology, and the University of Alberta exhibit marked increases in productivity. The National Institute of Education and The McPin Foundation also display consistent progression, indicating sustained institutional interest. By 2025, several affiliations converge at relatively high output levels, suggesting that research on reflective practice in inquiry-based physics education has become a shared priority across multiple global institutions. This

pattern underscores a broad institutional commitment that strengthens the field's stability and collaborative potential.

Analyzing the geographic distribution of corresponding authors helps illuminate which countries act as primary contributors to research on reflective practice within inquiry-based physics education. This view also highlights the balance between single-country output and internationally co-authored publications.

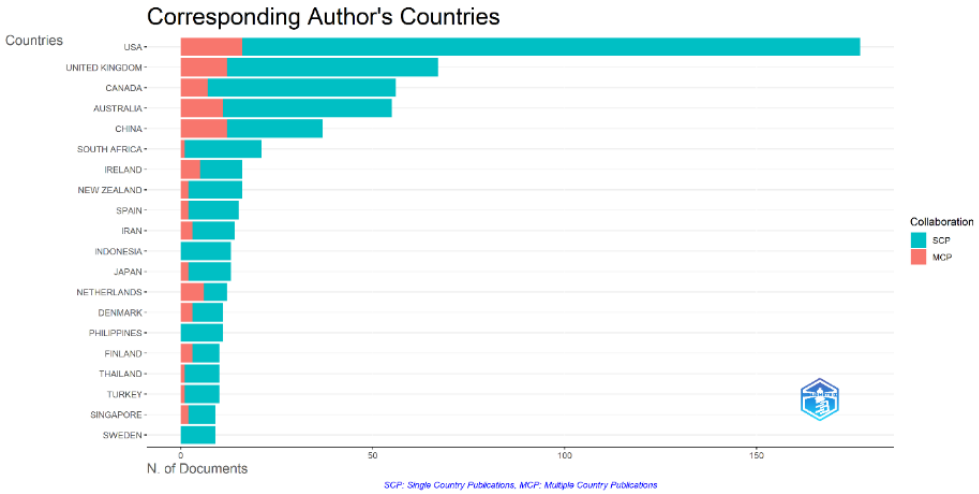



**Figure 16.** Corresponding Author's Countries

The chart shows that the USA overwhelmingly leads with the highest number of corresponding authors, followed by the United Kingdom, Canada, and Australia, demonstrating strong dominance of Western research hubs in this field. China and South Africa also appear as notable contributors, indicating broader global engagement. The balance between Single Country Publications (SCP) and Multiple Country Publications (MCP) varies across nations, with major contributors exhibiting substantial international collaboration. Overall, the distribution reflects an increasingly interconnected research landscape, where both national productivity and cross-country partnerships support the field's ongoing growth.

To complement the analysis of corresponding authors, mapping global scientific production provides a broader view of how different countries contribute to research on reflective practice within inquiry-based physics education. This geographic visualization highlights both regional concentrations and areas of emerging participation.

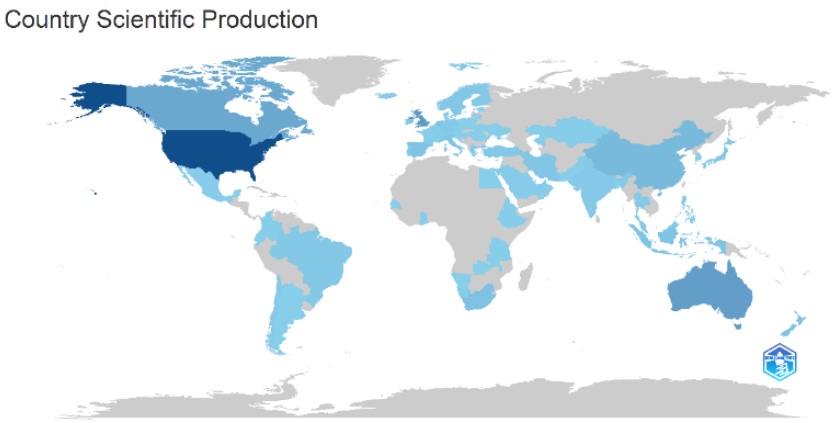



**Figure 17.** Countries' Scientific Production

The world map reveals a strong concentration of research output in North America, Western Europe, Australia, and parts of East Asia, with the United States standing out as the most dominant contributor. Countries such as Canada, the United Kingdom, Australia, China, and several European nations also show substantial productivity, forming a well-established global research cluster. Meanwhile, contributions from Africa, South America, and Southeast Asia appear more dispersed but notable, indicating growing engagement from diverse regions. Overall, the distribution underscores that although the field is led by a small set of high-producing countries, participation is increasingly expanding across the globe.

Figure 18 illustrates the temporal distribution of scientific publications by country from 2015 to 2025. The figure provides a longitudinal overview of national research productivity, allowing comparison of growth trends among major contributing countries in the field over the observed period.

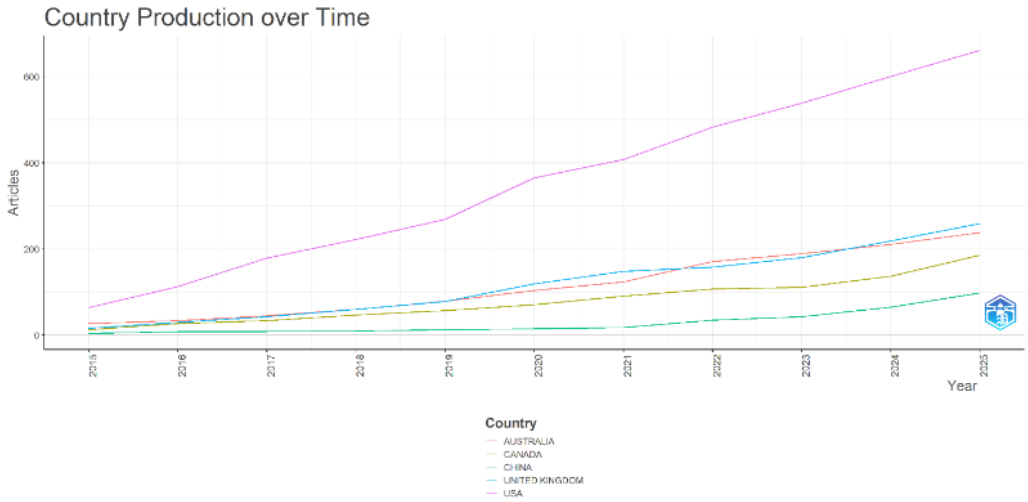



**Figure 18.** Countries' Production over Time

Overall, the figure shows a consistent increase in publication output across all countries, with the United States demonstrating the most dominant and sustained growth throughout the period. The United Kingdom and Australia also exhibit strong upward trends, particularly after 2020, indicating intensified research engagement. Meanwhile, Canada and China show steady but comparatively moderate growth, with China displaying a notable acceleration in recent years. These patterns suggest an expanding global interest in the research domain, alongside persistent disparities in national research productivity.

Figure 19 presents the most cited countries based on total citations (TC) and average citations per article. This figure highlights not only the volume of scholarly impact generated by each country but also the relative citation influence of individual publications, providing a complementary perspective to productivity-based indicators.

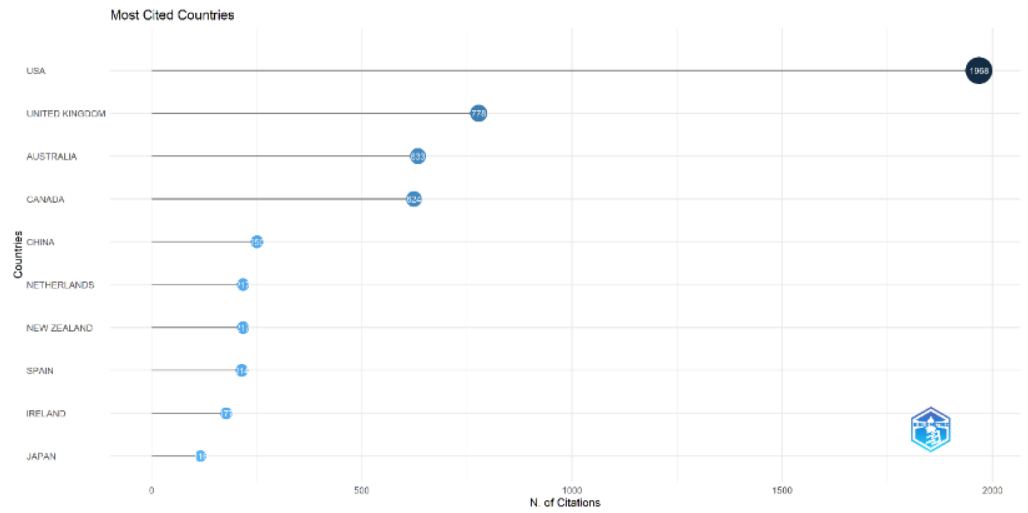



**Figure 19.** Most Cited Countries

The results indicate that the United States leads in total citations, reflecting its dominant publication volume and sustained influence in the field. The United Kingdom, Australia, and Canada also show strong citation performance with comparable average citations per article. Notably, several countries with lower total output, such as Malta, Korea, and the Netherlands, demonstrate exceptionally high average citation rates, suggesting that fewer but highly influential studies contribute substantially to their impact. Conversely, some countries exhibit lower average citations, indicating emerging or regionally focused research

contributions. Overall, these findings underscore disparities between research quantity and citation impact across countries.

Figure 20 summarizes the most globally cited documents in the dataset, reporting each paper's DOI, total citations (TC), citations per year, and normalized citation impact to highlight highly influential works.

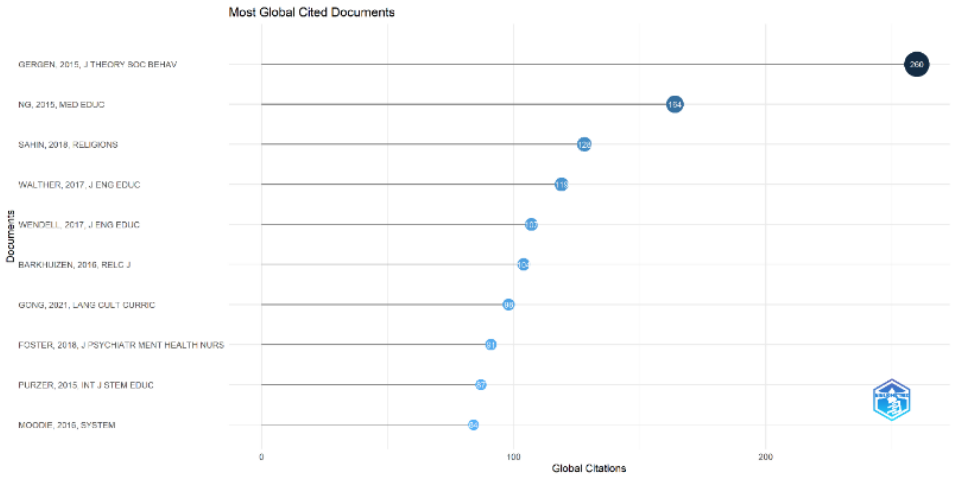



**Figure 20.** Most Global Cited Documents

The results show that a small set of papers concentrates the highest global influence, with several 2015–2018 publications leading in total citations, while some newer papers display strong TC per year and normalized TC, indicating rapidly growing impact despite shorter publication time.

Figure 21 shows the Most Local Cited Documents, indicating which papers are most frequently cited within the dataset (local citations), thereby identifying studies that are most central to the internal knowledge structure of this research field.

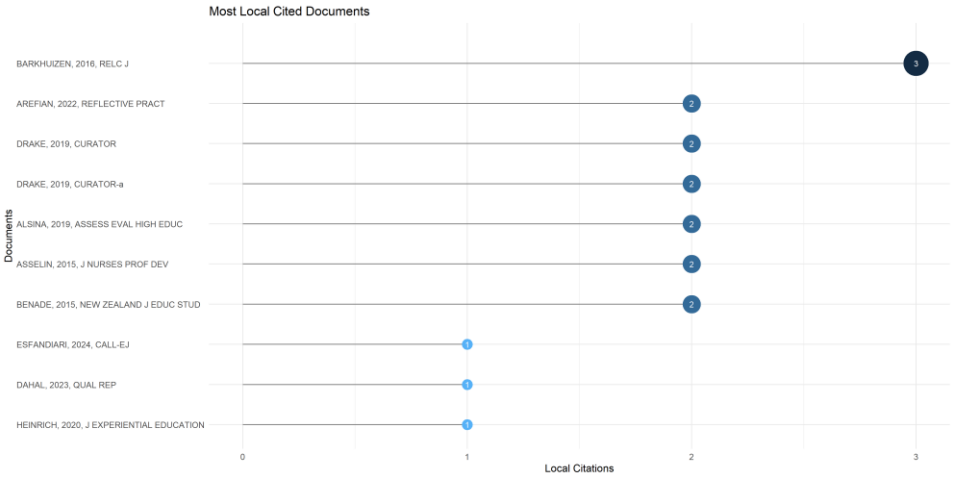



**Figure 21.** Most Local Cited Documents

The figure indicates that Barkhuizen (2016) has the highest local influence (3 local citations), followed by several documents with 2 local citations (e.g., Arefian, 2022; Drake, 2019; Alsina, 2019; Asselin, 2015; Benade, 2015). A smaller group of more recent works appears with 1 local citation, suggesting emerging contributions that are beginning to be integrated into the field's internal citation network.

Figure 22 displays the most locally cited references within the dataset, highlighting foundational works that are most frequently referenced by the analyzed publications and therefore play a central role in shaping the theoretical and methodological framework of the field.

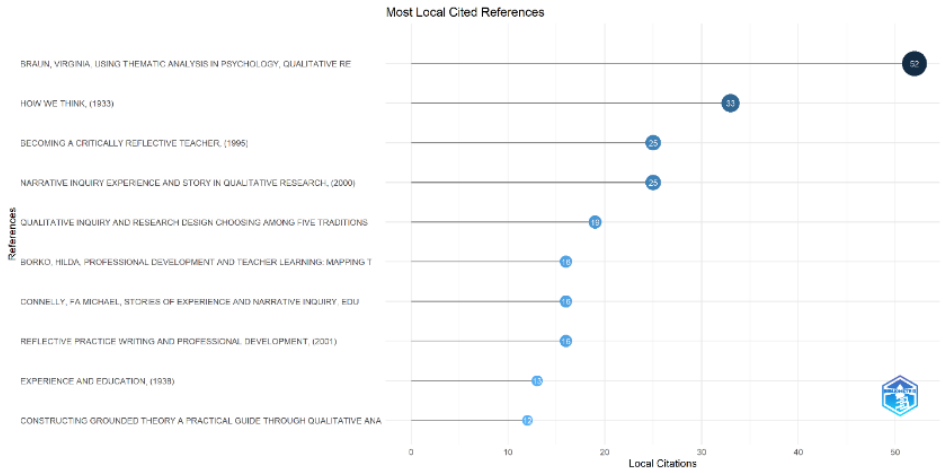



**Figure 22.** Most Local Cited References

The results show that classic and methodological references dominate local citations, with Braun and Clarke's work on thematic analysis receiving the highest number of local citations, underscoring the strong qualitative orientation of the field. Seminal works on reflective thinking and experiential learning, such as How We Think and Experience and Education, also feature prominently, indicating enduring theoretical influence. Additionally, references related to narrative inquiry, grounded theory, and teacher professional development suggest that reflective practice research is deeply rooted in interpretive and practice-based research traditions.

Figure 23 presents the Reference Publication Year Spectroscopy (RPYS), which visualizes the distribution of cited references by publication year. This analysis is used to identify historically influential works and seminal periods that have shaped the intellectual foundations of the research field.

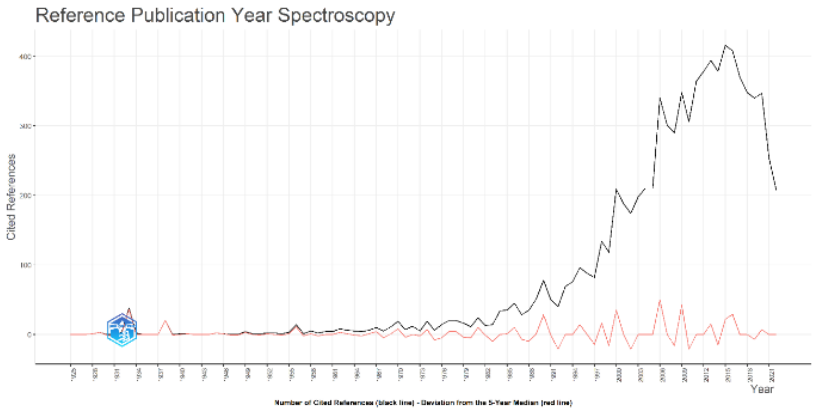



**Figure 23.** Reference Spectroscopy

The RPYS results reveal pronounced peaks corresponding to key publication years, indicating the presence of highly influential foundational works. Early peaks reflect classic theoretical contributions, while a substantial increase in cited references from the late 1990s onward suggests consolidation and expansion of methodological and empirical research in the field. The strong growth in recent decades highlights the increasing reliance on contemporary scholarship, alongside continued citation of seminal works, demonstrating both theoretical continuity and evolving research directions.

Figure 24 presents the most frequent words appearing in the analyzed publications. This visualization highlights dominant themes and recurring concepts that characterize the overall research focus within the dataset.

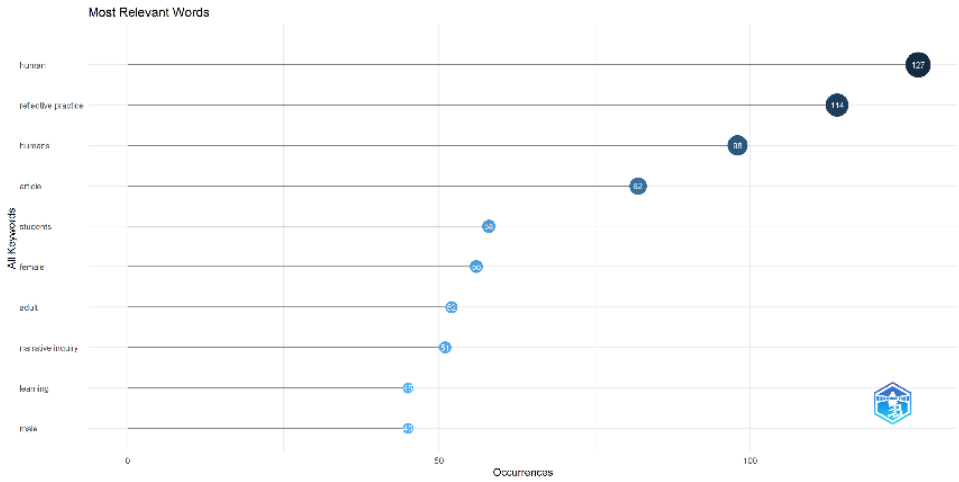



**Figure 24.** Most Frequent Words

The results indicate that terms related to human participants and reflective processes dominate the dataset, with "human(s)" and "reflective practice" emerging as the most frequent keywords. Educationally oriented terms such as students, learning, and narrative inquiry further emphasize the pedagogical and qualitative orientation of the field. The presence of demographic descriptors (e.g., adult, female, male) suggests that many studies explicitly report participant characteristics, reflecting methodological rigor in educational and social research contexts. Overall, the keyword distribution confirms a strong emphasis on reflective, human-centered learning processes.

Figure 25 presents the trend topics analysis, illustrating the temporal emergence and evolution of key research terms across the study period. The figure highlights when specific topics gain prominence and how their relevance develops over time based on term frequency.

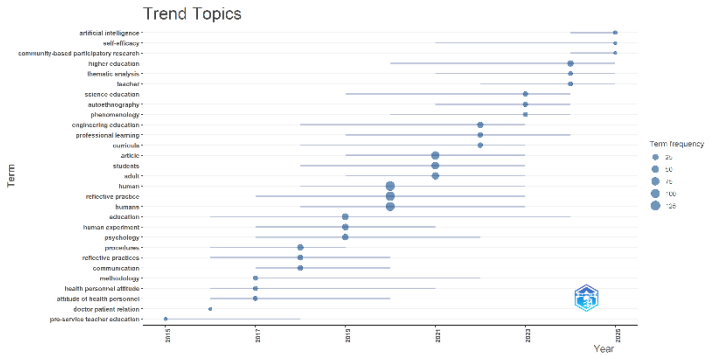



**Figure 25.** Trend Topics

The figure indicates that foundational topics such as reflective practice, human(s), education, and students have persisted throughout most of the study period, reflecting their sustained centrality in the field. More recent years show the emergence of methodological and context-specific topics, including thematic analysis, autoethnography, and phenomenology, suggesting a growing emphasis on qualitative and reflective methodologies. Additionally, topics such as engineering education, science education, and professional learning appear increasingly after 2020, indicating diversification of application domains. Emerging terms like artificial intelligence and self-efficacy in the most recent years point to evolving research directions that integrate reflective practice with technological and psychological perspectives.

Figure 26 presents the thematic clustering based on documents coupling analysis. This map positions clusters according to their centrality and impact, allowing identification of dominant, emerging, and peripheral research themes within the field.

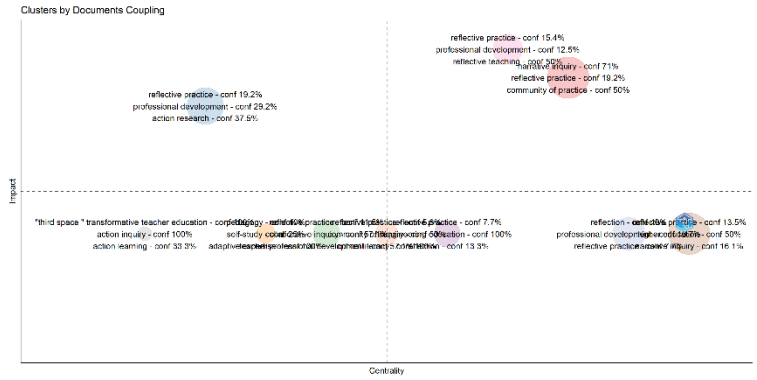



**Figure 26.** Clustering by Coupling

The figure reveals several distinct thematic clusters with varying degrees of centrality and impact. Highly central and impactful clusters are dominated by themes such as reflective practice, professional development, narrative inquiry, and community of practice, indicating that these topics form the intellectual core of the field. Clusters with high impact but lower centrality, including action research and reflective teaching, suggest specialized yet influential research directions. Meanwhile, clusters positioned with lower impact and centrality such as self-study, action learning, and third space represent emerging or niche themes that contribute to conceptual diversification. Overall, the coupling structure indicates a mature research domain anchored in reflective practice while continuing to expand through methodological and contextual innovations.

Figure 27 illustrates the keyword co-occurrence network, visualizing relationships among frequently used terms based on their simultaneous appearance within documents. The network structure highlights thematic groupings and the strength of conceptual connections across the research field.

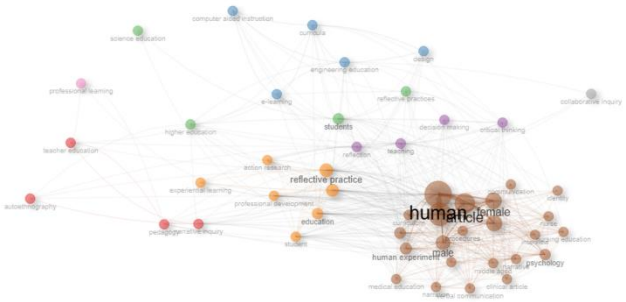



**Figure 27.** Co-occurrence Network

The network reveals a densely connected core centered on human, reflective practice, and education, indicating that these concepts form the conceptual backbone of the field. Surrounding clusters link reflective practice with professional development, students, teaching, and experiential learning, suggesting strong integration between reflection and pedagogical processes. Additional clusters associated with psychology, narrative inquiry, communication, and medical or nursing education demonstrate the interdisciplinary nature of the research. Overall, the co-occurrence structure reflects a mature and interconnected knowledge domain in which reflective practice functions as a central bridge connecting educational, professional, and human-centered research themes.

Figure 28 presents the thematic map based on keyword co-occurrence, positioning themes according to their relevance (centrality) and development (density). This map categorizes themes into motor, basic, niche, and emerging or declining themes, providing a structured overview of the conceptual organization of the research field.

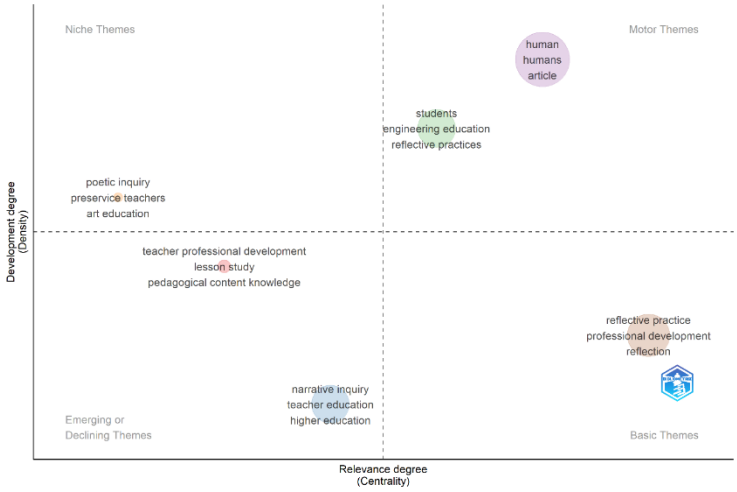



**Figure 28.**Thematic Map

The thematic map shows that human(s) and article constitute motor themes, indicating highly developed and central topics that drive the field. Reflective practice, professional development, and reflection appear as basic themes, highlighting their foundational role and strong connectivity despite moderate internal development. Themes related to students, engineering education, and reflective practices are positioned between motor and basic areas, suggesting applied and pedagogically oriented research with growing coherence. In contrast, narrative inquiry, teacher education, and higher education are located within the emerging or declining quadrant, indicating either developing research fronts or shifting scholarly attention. Finally, poetic inquiry, art education, and preservice teachers emerge as niche themes, reflecting specialized but well-developed lines of inquiry with limited integration into the broader field.

Figure 29 presents the conceptual structure of the research field using Multiple Correspondence Analysis (MCA) combined with hierarchical clustering. This analysis identifies latent thematic dimensions and groups keywords based on their co-occurrence patterns, revealing the underlying conceptual organization of the literature.

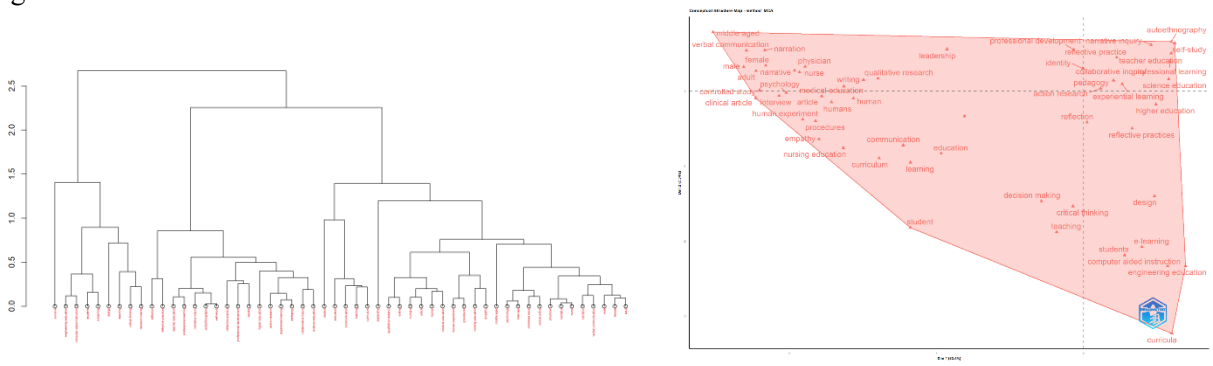



**Figure 29.** Factorial Analysis

The conceptual structure map reveals a clear separation of thematic dimensions, indicating distinct yet interconnected research orientations. One major cluster is dominated by human-centered and qualitative research terms such as human, humans, psychology, narrative inquiry, interview, and medical or nursing education, reflecting a strong interpretive and experiential research tradition. Another cluster emphasizes educational and pedagogical applications, including students, teaching, learning, engineering education, e-learning, and computer-aided instruction, suggesting a focus on instructional design and learning environments. Keywords related to reflective practice, professional development, action research, and teacher education occupy intermediary positions, functioning as conceptual bridges between methodological and pedagogical domains. Overall, the MCA results indicate that reflective practice research is structured around complementary qualitative and educational dimensions, highlighting its role as an integrative framework across disciplinary and methodological boundaries.

Figure 30 presents the co-citation network of referenced documents, illustrating how frequently pairs of references are cited together within the dataset. This network reveals the intellectual structure of the field by identifying foundational works and major theoretical and methodological influences.

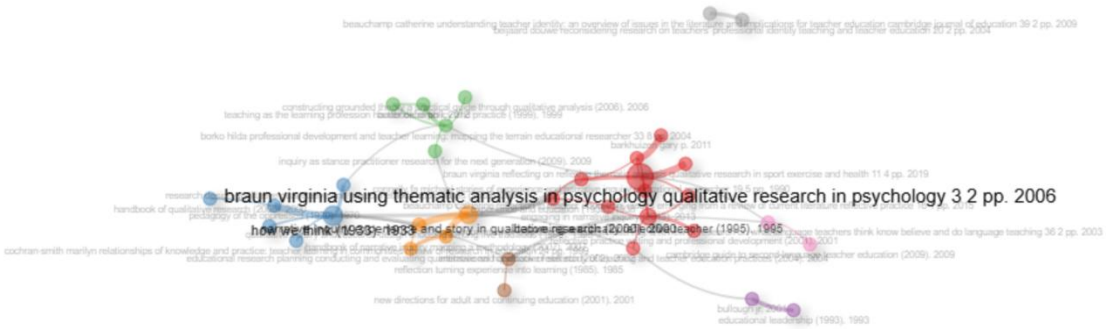



**Figure 30.** Co-citation Network

The co-citation network highlights a core group of highly influential references that anchor the field, with Braun and Clarke's work on thematic analysis occupying a central position, reflecting its widespread methodological adoption. Classic theoretical contributions on reflective thinking and experiential learning, such as How We Think and Experience and Education, are closely interconnected with studies on narrative inquiry and teacher professional development. The presence of distinct yet linked clusters suggests that the field is structured around complementary traditions, including qualitative methodology, reflective practice, and educational research. Overall, the network indicates a cohesive intellectual foundation in which seminal works continue to inform and connect contemporary reflective practice scholarship.

Figure 31 presents the global collaboration network among countries based on co-authorship patterns. The map visualizes international research linkages, illustrating the geographic distribution and intensity of cross-country collaborations within the field.

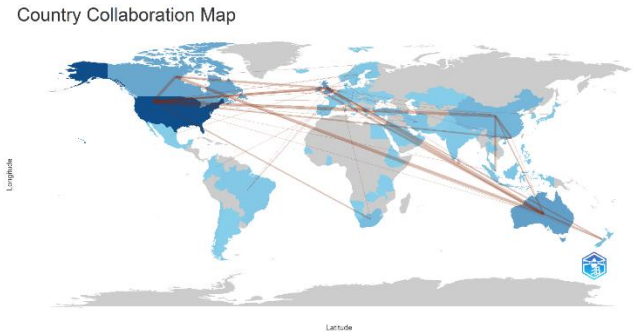



**Figure 31.** Countries' Collaboration World Map

The map indicates that research collaboration is concentrated among a small number of highly connected countries, with the United States, the United Kingdom, and Australia acting as major hubs of international collaboration. Strong collaborative ties are also observed between Europe, North America, and the Asia–Pacific region, reflecting transcontinental research partnerships. In contrast, many regions show limited connectivity, suggesting uneven global participation. Overall, the collaboration pattern highlights the central role of established research systems while pointing to opportunities for expanding international collaboration to underrepresented regions in future studies.

**Discussion**

The bibliometric evidence indicates that research on reflective practice in inquiry-based physics education (IBPE) has transitioned from a peripheral concern to a sustained and expanding scholarly domain. The steady annual growth rate (9.88%) and the relatively young average document age (4.04 years) suggest that the field is not only active but also continually renewing its research agenda. This trajectory supports the broader claim in contemporary science education that reflection strengthens inquiry by fostering metacognition, evidence-based reasoning, and adaptive decision-making—competencies increasingly emphasized in 21st-century learning frameworks.

***Growth Patterns and the Post-2020 Acceleration***

The sharp increase in annual scientific production after 2020 is noteworthy. While citation-lag effects explain why older papers receive higher average citations per year, the post-2020 productivity surge likely reflects systemic shifts in education research priorities during and after the pandemic era: increased attention to student-centered learning, teacher adaptability, and reflective teaching in hybrid or disrupted learning environments. Importantly, the growth in volume may be outpacing the consolidation of impact, as seen in declining average citations per article in recent years. This pattern is typical of fast-expanding fields where topical diversification occurs before canonical works stabilize and become widely cited.

***Publication Venues: Interdisciplinary Identity and a Dual-Core Structure***

The source analysis reveals a dual identity of the field. On the one hand, Reflective Practice dominates productivity, signaling that the research community frequently positions reflective inquiry within teacher learning and professional development discourses. On the other hand, the strongest local citation impact clusters around science/physics education outlets such as Physics Education, International Journal of Science Education, and Research in Science Education. This split suggests an intellectual structure where reflective practice scholarship is often published and framed in reflective/qualitative education journals, yet its domain-specific influence is consolidated in science education venues.

Bradford's Law patterns further reinforce that a small set of core journals anchors dissemination, while a wide periphery of journals broadens the interdisciplinary reach. While this scattering can be productive for cross-fertilization, it also creates fragmentation: reflective tools and constructs may travel across disciplines under different labels (e.g., narrative inquiry, practitioner research, professional learning), making it harder to aggregate evidence for physics-specific instructional design.

***Authorship Structure: Concentrated Productivity, Collaborative Norms***

The absence of single-authored papers and the high mean number of co-authors per document indicate that the field is strongly collaborative. At the same time, Lotka's Law confirms a highly skewed productivity distribution, where a small cohort produces a large share of outputs. This combination high collaboration but concentrated productivity suggests a network with "core" research groups sustaining momentum, while many authors contribute episodically.

Such a structure can accelerate methodological diffusion (e.g., adoption of Biblioshiny, VOSviewer, thematic analysis) through stable teams, but it may also narrow conceptual diversity if dominant groups set the framing of "reflection" primarily through teacher education or qualitative paradigms. To maintain innovation, the field may benefit from stronger bridges between core clusters and peripheral contributors, especially those working on physics-specific inquiry practices (measurement, modeling, uncertainty).

***Institutional and Geographic Concentration: Global Expansion with Uneven Participation***

Institutional analysis highlights several leading universities (e.g., Deakin University, University of Alberta, Queensland University of Technology) acting as productive hubs. Country-level results show strong dominance of the United States, followed by the United Kingdom, Australia, and Canada, both in output and citation volume. The collaboration map positions these countries as central connectors in international co-authorship networks.

However, the distribution also reflects persistent inequities: regions such as Southeast Asia, much of Africa, and South America appear less central in the collaboration network. This matters because reflective practice is deeply shaped by contextual factors—curriculum constraints, assessment regimes, cultural norms around classroom dialogue, and resource availability. Limited global representation can therefore reduce the field's capacity to generate context-responsive reflective-inquiry models and may bias what counts as "effective" reflection toward Western instructional conditions.

***Conceptual Focus: Reflection as a Human-Centered, Qualitative Enterprise***

Keyword frequency, co-occurrence mapping, thematic mapping, and MCA collectively show a strongly human-centered and qualitatively oriented domain. Core terms (e.g., human(s), reflective practice, students, learning, teaching, professional development, narrative inquiry) indicate that reflective practice research within IBPE is often framed through experience, identity, and professional growth. The prominence of references such as Braun and Clarke (thematic analysis) and classic reflective learning foundations further supports this methodological and epistemological orientation.

While this qualitative emphasis is valuable especially for capturing reflective meaning-making it can also signal a missed opportunity: physics inquiry carries distinctive epistemic demands (e.g., model

evaluation, uncertainty reasoning, representational fluency, data-based argumentation). Yet physics-specific reflective mechanisms (reflection on measurement error, model revision, computational reasoning, epistemic cognition in physics) are not strongly visible in the dominant keyword landscape, which appears more generic and cross-disciplinary. This suggests that IBPE may still lack a clearly articulated, widely shared framework for what "reflection" looks like when it is embedded in authentic physics practices.

***Thematic Map Implications: A Mature Core and Underdeveloped Physics-Specific Frontiers***

The thematic map positions human(s) and article as motor themes, while reflective practice and professional development appear as basic themes highly connected but not necessarily conceptually dense. This configuration implies a mature, stable foundation: reflection is central, but its internal theoretical sophistication may not be developing as rapidly as its spread across contexts.

Meanwhile, teacher education, higher education, and narrative inquiry are located in the emerging/declining space, which can be interpreted in two ways. First, these themes may be transitioning either becoming integrated into broader reflective practice discourse (thus losing distinctiveness) or being replaced by newer concerns (e.g., AI, self-efficacy, e-learning). Second, it may reflect changing methodological fashions rather than substantive decline. Either way, the field appears open for a new wave of physics-specific reflective-inquiry studies that connect reflection to modeling, uncertainty, and argumentation the "metacognitive promise" of inquiry that is particularly salient in physics.

***Emerging Topics: Technology, AI, and Psychological Constructs Still Peripheral***

Trend topic analysis indicates that terms such as artificial intelligence, self-efficacy, and digitally mediated learning have begun to appear in the most recent period. This suggests an emerging convergence between reflective practice and data-rich learning environments (e.g., learning analytics, AI-supported feedback, intelligent tutoring, or computational notebooks). Yet these themes remain peripheral relative to the dominant reflective and qualitative clusters, implying that the integration of advanced technologies into reflective inquiry is still nascent.

This is a key opportunity: technology can operationalize reflection in more traceable ways (e.g., automated prompts, reflection dashboards, revision histories in computational notebooks, AI-supported feedback on reasoning). If future research explicitly links these tools to physics-specific inquiry competencies (e.g., uncertainty reasoning, model refinement), it could address the field's current limitation of relying heavily on generic reflective constructs.

***Practical and Research Implications***

The bibliometric mapping suggests that although reflective practice is widely recognized as an essential component of inquiry-based physics education, it is often implemented in relatively generic forms, such as learning journals or narrative reflections, rather than being systematically embedded within the core epistemic cycles of physics inquiry. For instructional practice, this indicates the need to design structured reflection routines that explicitly target physics-specific epistemic moves, including articulating and revisiting assumptions, evaluating measurement uncertainty, revising and comparing models, justifying representational choices, and reflecting on the limits and validity of empirical evidence. From a research perspective, the findings highlight several priorities for advancing the field. Future studies should provide greater operational clarity by differentiating reflective mechanisms in terms of prompt design, timing, and social configuration, as well as distinguishing reflection-on-action from reflection-in-action within IBPE interventions. There is also a clear need to strengthen physics specificity by linking reflective practice directly to core inquiry components such as model-based reasoning, uncertainty analysis, and computational thinking. Methodologically, expanding beyond predominantly qualitative approaches toward mixed-method and experimental designs would enable more robust testing of which reflective tools generate measurable learning gains. In addition, increasing participation and leadership from underrepresented regions is crucial for contextualizing reflective inquiry models and enhancing their global relevance. Finally, emerging opportunities lie in investigating AI- and digitally supported reflection, particularly where such technologies can scaffold reflective processes in ways that remain aligned with authentic physics practices.

## CONCLUSION

This bibliometric analysis shows that reflective practice has become a prominent and growing component of inquiry-based physics education between 2015 and 2025, supported by increasing publication

output and a well-established conceptual foundation. However, the findings reveal that reflective practice is still largely framed in generic and teacher-centered ways, with limited integration into physics-specific epistemic processes such as modeling, uncertainty analysis, and evidence-based reasoning. This indicates that the full potential of reflection to strengthen physics inquiry has not yet been realized. Future research should therefore focus on developing physics-specific reflective frameworks, employing more rigorous mixed-method and experimental designs, expanding contributions from underrepresented regions, and exploring technology- and AI-supported reflection to enhance the effectiveness of inquiry-based physics education.

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## AUTHORS' CONTRIBUTIONS

**Hanan Zaki Alhusni** contributed to the formulation of the research idea, study design, data collection, bibliometric analysis, and manuscript drafting. **Binar Kurnia Prahani** contributed to developing the research framework, supervising the bibliometric methodology, and critically reviewing the manuscript. **Titin Sunarti** contributed to data interpretation, validation of the analysis results, and refinement of the discussion section. **Riski Ramadani** contributed to methodological guidance, interpretation of findings, and overall manuscript evaluation. **Salma Hasna Hamiyda** contributed to data processing, visualization of bibliometric results, and manuscript editing.

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