Salud, Ciencia y Tecnología. 2025; 5:2402
doi: 10.56294/saludcyt20252402

ORIGINAL

Problem-Based Learning and Higher-Order Thinking Skills: A Scopus-Based Bibliometric Analysis of Trends, Sources, and Collaboration Networks

Aprendizaje basado en problemas y habilidades de pensamiento de orden superior: un análisis bibliométrico basado en Scopus de tendencias, fuentes y redes de colaboración

Rona Rossa[1], M. Zaim[1], Mukhaiyar[1]

[1]Universitas Negeri Padang, Doctoral Program Study in Language Teaching, Universitas Padang. Indonesia.

Cite as: Rossa R, Zaim M, Mukhaiyar. Problem-Based Learning and Higher-Order Thinking Skills: A Scopus-Based Bibliometric Analysis of Trends, Sources, and Collaboration Networks. Salud, Ciencia y Tecnología. 2025; 5:2402. https://doi.org/10.56294/saludcyt20252402

Submitted: 24-03-2025 **Revised:** 15-07-2025 **Accepted:** 29-10-2025 **Published:** 30-10-2025

Editor: Prof. Dr. William Castillo-González

Corresponding Author: Rona Rossa

ABSTRACT

Introduction: this study systematically mapped research developments on Problem-Based Learning and Higher-Order Thinking Skills in higher education using a bibliometric approach.
Method: data were collected from the Scopus database using keyword combinations, yielding 41 documents published between 1997 and 2025. Formal analysis included publication trend charting, co-occurrence mapping (VOSviewer), and citation analysis to examine the structural and intellectual landscape.
Results: publications peaked in 2020 (13 documents) and were dominated by Conference Papers. The research was highly concentrated in Physics and Astronomy (35,6 %) and was overwhelmingly led by Indonesia, with Universitas Sebelas Maret being the most productive institution. The analysis confirmed the seminal work by Hmelo and Ferrari (1997) as the theoretical foundation, while contemporary efforts focused on quantitative validation and technological integration (e.g., e-modules).
Conclusions: the field experienced a rapid growth phase driven by global educational shifts. The strong regional dominance establishes a need for comparative studies to enhance the external validity of the successful Problem-Based Learning models developed in the region. Future research should prioritize systematic literature reviews to consolidate the empirical evidence base.

Keywords: Problem-Based Learning; Higher-Order Thinking Skills; Bibliometric Analysis; Scopus, Educational Research; Higher Education.

RESUMEN

Introducción: este estudio mapeó sistemáticamente los desarrollos de la investigación sobre el aprendizaje basado en problemas y las habilidades de pensamiento de orden superior en la educación superior utilizando un enfoque bibliométrico.
Método: los datos se recolectaron de la base de datos Scopus utilizando combinaciones de palabras clave, arrojando 41 documentos publicados entre 1997 y 2025. El análisis formal incluyó gráficos de tendencias de publicación, mapeo de coocurrencia (VOSviewer) y análisis de citas para examinar el panorama estructural e intelectual.
Resultados: las publicaciones alcanzaron su punto máximo en 2020 (13 documentos) y estuvieron dominadas por Conference Papers. La investigación se concentró en gran medida en Física y Astronomía (35,6 %) y fue liderada abrumadoramente por Indonesia, siendo la Universitas Sebelas Maret la institución más productiva. El análisis confirmó el trabajo seminal de Hmelo y Ferrari (1997) como fundamento teórico, mientras que los esfuerzos contemporáneos se centraron en la validación cuantitativa y la integración tecnológica (por ejemplo, módulos electrónicos).

© 2025; Los autores. Este es un artículo en acceso abierto, distribuido bajo los términos de una licencia Creative Commons (https://creativecommons.org/licenses/by/4.0) que permite el uso, distribución y reproducción en cualquier medio siempre que la obra original sea correctamente citada

Conclusiones: el campo experimentó una fase de rápido crecimiento impulsada por los cambios educativos globales. El fuerte dominio regional establece la necesidad de estudios comparativos para mejorar la validez externa de los exitosos modelos de Aprendizaje Basado en Problemas desarrollados en la región. La investigación futura debe priorizar las revisiones sistemáticas de la literatura para consolidar la base de evidencia empírica.

Palabras clave: Aprendizaje Basado en Problemas; Habilidades de Pensamiento de Orden Superior; Análisis Bibliométrico; Scopus; Investigación Educativa; Educación Superior.

INTRODUCTION

The contemporary global economy is defined by rapid technological advancements, characterized by the pervasive influence of artificial intelligence, automation, and continuous innovation.[1,2,3] This environment has irrevocably transformed the demands of the labor market, rendering traditional, rote-learning models obsolete. Educational institutions worldwide, particularly those in higher education, are facing an existential mandate to shift their focus from mere knowledge transmission to the cultivation of sophisticated cognitive skills abilities that machines cannot easily replicate.[4,5] This crucial set of competencies is universally recognized as Higher-Order Thinking Skills (HOTS). The pedagogical challenge, therefore, lies in adopting instructional strategies that actively and effectively catalyze the development of these advanced skills. In this pivotal context, Problem-Based Learning (PBL) has emerged as the quintessential student-centered approach, serving as the most researched and acclaimed mechanism for fostering the intellectual agility required by the twenty-first century.[6,7] This study is premised on the necessity of providing a systematic, macro-level synthesis of the intricate and expansive relationship between PBL and HOTS across the global academic landscape.[8,9,10,11]

To fully appreciate the convergence of PBL and HOTS, it is essential to trace their distinct historical trajectories and understand why they have become pedagogically inseparable. The concept of HOTS has its foundational roots in the field of educational psychology, most prominently formalized by Benjamin Bloom's Taxonomy of Educational Objectives, published in 1956. This pioneering framework established a hierarchy of cognitive goals, structurally distinguishing between Lower-Order Thinking Skills (LOTS)—such as remembering and understanding and the superior intellectual processes that involve analysis, evaluation, and synthesis (later revised to creation).[12] The introduction of this taxonomy immediately framed a new aspiration for curriculum developers: to move educational practice beyond surface-level recall toward deep intellectual engagement. The subsequent revision of Bloom's Taxonomy, known as the Revised Taxonomy, shifted the terminology from nouns to action verbs, emphasizing that thinking is not a static attribute but a dynamic, active process of analyzing, evaluating, and creating. This evolution firmly embedded the pursuit of HOTS into global educational standards, recognizing that these skills are essential for problem-solving in novel, ill-defined situations, making them the ultimate goal of effective teaching and learning.[13,14]

Concurrently, PBL developed along a parallel but distinct path, born out of a profound dissatisfaction with the limitations of the traditional lecture method in professional education. Originating at the McMaster University Medical School in the 1960s, PBL was conceived as a radical solution to the problem of "inert knowledge," the phenomenon where medical students possessed vast theoretical knowledge but failed to apply it effectively to real clinical cases.[15] PBL fundamentally reverses the traditional teaching order: students are first presented with an authentic, complex, and ill-structured problem, a problem with no single correct answer and incomplete initial information, and are subsequently required to acquire the necessary knowledge to solve it. This instructional design principle forces students to engage in self-directed learning, collaborative inquiry, and hypothesis generation.[16,17,18] Crucially, the very nature of PBL, which demands the identification of knowledge gaps, the critical evaluation of information sources, and the construction of a novel solution, is intrinsically aligned with the definition of HOTS. The problem serves not merely as an application exercise, but as the catalyst for analytical, evaluative, and creative thinking. This pedagogical mechanism successfully bridges the gap between theoretical understanding and practical application, cementing PBL's reputation as the gold standard for cultivating advanced cognitive skills across disciplines, from engineering and business to education and the social sciences.[19,20]

The convergence of these two powerful concepts in academic research is no coincidence; it signifies a mature consensus in educational science that PBL is the most effective way to achieve the HOTS.[21] Since the seminal work by Hmelo[12], the literature has consistently demonstrated that the cognitive load imposed by solving authentic problems within the PBL framework pushes students out of their comfort zone, compelling them to employ deep processing strategies and metacognitive skills the very essence of HOTS.[22,23,24]

The contemporary academic landscape confirms the intensity and relevance of the PBL–HOTS nexus. This field is no longer a niche area but a major domain of educational research, as statistically evidenced by

the significant and sustained surge in global publications recorded in authoritative databases like Scopus. An analysis of publication trends reveals a particularly steep ascent in the volume of articles focusing on PBL and HOTS between 2018 and 2023, with notable peaks in production, demonstrating that this topic has moved from a theoretical debate to an urgent, applied research priority worldwide.[5,25] This statistical growth reflects a strong worldwide dedication to educational reform focused on skill development enhancement.

A deeper examination of the current research output highlights several dominant, interconnected main lines of investigation that are actively shaping the field. First, there is substantial research focused on Pedagogical Refinement and Hybridization of PBL Models.[26,27] Scholars are actively investigating how to optimize PBL for specific educational contexts and student demographics. This includes studies on Scaffolding PBL to provide structured support for novice learners in vocational and STEM fields, the integration of Flipped Classroom methodologies with PBL to maximize class time for higher-order activities, and the embedding of character education or computational thinking within the problem-solving process.[14,28,29] Second, a critical research line explores the role of Technology and Digital Contexts. With the acceleration of blended and distance learning, particularly post-2020, studies are heavily invested in determining the efficacy of digital tools, such as interactive e-modules, digital simulation games, and virtual learning environments, in delivering PBL and facilitating the measurement of HOTS in remote settings.[14] This strand addresses the essential question of how to maintain pedagogical quality when physical classroom interaction is limited.

Third, Disciplinary Application and Assessment remains a robust area. While PBL originated in medical education, current research shows a strong diversification, with significant contributions coming from Physics, Astronomy, and the Social Sciences. This research often focuses on developing and validating context-specific assessment instruments designed to reliably measure the gains in HOTS—such as critical thinking and analytical reasoning—resulting from PBL implementation.[5] Fourth, there is a growing interest in the Holistic Student Development angle, linking the cognitive gains of HOTS fostered by PBL with affective and non-cognitive outcomes. Studies explore the correlation between the PBL experience and improvements in student motivation, self-efficacy, collaborative skills, and communication factors that are integral to successful real-world application of HOTS.

Despite this rich and statistically significant research output, the existing body of knowledge suffers from acute fragmentation. Much of the published research is based on short-term experimental studies confined to a single institution or specific discipline, offering only localized conclusions.[30] Furthermore, while the volume of literature has soared, a comprehensive, high-level synthesis is critically lacking. Prior review studies have often been limited to narrow time frames, focused exclusively on one side of the nexus (PBL or HOTS), or employed descriptive narrative methods that fail to capture the quantitative dynamics of the field's intellectual structure. This fragmentation means the academic community currently lacks an authoritative, data-driven map that systematically identifies the leading intellectual drivers, global collaboration networks, and the most influential thematic clusters that have defined the evolution of PBL–HOTS research over the past three decades.[30] This gap prevents policymakers, curriculum designers, and new researchers from efficiently pinpointing global centers of expertise and the most promising avenues for future research.[31]

The demonstrable fragmentation in the existing literature provides a strong justification for the present study. While numerous empirical studies confirm the positive effects of PBL on HOTS, what remains missing is a quantitative, macro-level synthesis that captures the entire developmental arc of this field since its inception. A robust Scopus-based bibliometric analysis is required to transcend the limitations of traditional qualitative reviews, providing an evidence-based structural mapping of the field's intellectual architecture.[32] The use of bibliometrics, which analyzes publication output, citation patterns, and collaboration networks, is the ideal methodological approach to consolidate this dispersed knowledge, especially across a long time frame (1997–2025) and diverse disciplinary contributions. This study will move beyond simple data aggregation to reveal the underlying thematic connections and global power dynamics that govern the research domain.

The significance of this research is two-fold: Theoretically, it will identify the most frequently cited works and authors, thereby establishing the intellectual backbone and seminal theories that underpin the PBL–HOTS nexus. By visualizing keyword co-occurrence, the study will delineate the major thematic clusters (e.g., assessment instruments, digital integration models, specific disciplinary applications) that have driven scholarly discourse. Practically, the findings will serve as an essential resource for educational leaders and policymakers. By identifying the most productive institutions (e.g., Universiti Pendidikan Sultan Idris, Universitas Sebelas Maret) and the most contributing countries (e.g., Indonesia), the study pinpoints established centers of excellence, facilitating resource allocation, guiding international collaboration strategies, and ensuring that curriculum development is informed by the most validated and influential research trajectories in the world.[33] Therefore, the primary objective of this study is to systematically map and analyze the global research developments on PBL and Higher-Order Thinking Skills HOTS using a comprehensive bibliometric analysis of the Scopus database from 1997 to 2025.

In order to systematically address the existing fragmentation and establish a clear intellectual architecture

for the PBL–HOTS research domain, this study articulates five specifics, interconnected secondary objectives, all aimed at delivering the necessary macro-level synthesis. These objectives begin with a quantitative analysis by aiming to delineate the annual publication trends and growth trajectory of the PBL–HOTS research domain from 1997 to 2025, providing statistical evidence of the field's maturity and research momentum. Building upon volume, the next step is to analyze the distribution of document types and identify the most prolific publication sources, including leading journals and conference proceedings, thereby guiding future authors toward high-impact venues and clarifying the primary dissemination channels for research findings. Following this, the study aims to determine the primary disciplinary orientations and the geographical distribution of contributions, examining both national and institutional levels to pinpoint global centers of excellence and identify which fields are most actively integrating the PBL–HOTS approach.[34,35,36,37]

Moving from descriptive statistics to intellectual structure, the fourth objective is to map the co-occurrence of author keywords to identify and visualize the major thematic clusters, such as assessment instruments, technology integration, or specific subject applications, that define the core intellectual debates and future research trajectories within the field.[38] Finally, to understand the social and influential dynamics, the research seeks to uncover and analyze the author collaboration network and identify the most influential authors and highly cited articles that constitute the foundational, theoretical, and methodological literature of the PBL–HOTS nexus.[39] Collectively, these objectives ensure that the study provides a comprehensive, data-driven map for all stakeholders seeking to navigate and advance research in this critical educational domain. By fulfilling these objectives, this research provides the necessary panoramic, evidence-based view required for the field's strategic advancement, offering clear guidance for future scholarly inquiry and educational innovation in the quest to cultivate true twenty-first-century competencies.

METHOD

The methodology adopted in this study is a bibliometric analysis, a robust, quantitative research approach specifically designed to map the evolution and intellectual structure of scientific literature within a defined domain.[40,41] This approach is non-observational, relying solely on publicly available publication metadata rather than primary data collection from human participants.[39]

Type of Study

This study is classified as non-observational and quantitative-descriptive research. Given the objective to systematically map and analyze the trends, sources, and collaboration networks related to Problem-Based Learning and Higher-Order Thinking Skills, the bibliometric approach is employed to achieve a macroscopic, data-driven overview of the academic field.[42] The study uses metadata variables (e.g., publication year, source, country, keywords, citations) derived from a large-scale database to describe the intellectual landscape without manipulating any variables or directly interacting with the subjects of the publications.[32]

Universe and Sample

Universe

The universe of this study encompasses all scientific literature published globally, specifically those indexed in the Scopus database. Scopus was selected as the sole database due to its renowned coverage of peer-reviewed literature across major disciplines, comprehensive citation indexing, and the quality of its structured metadata, which is optimal for bibliometric software analysis.[40] The time frame for the universe was set from the earliest indexed record to the date of data retrieval, which spans from 1997 to February 23, 2025.

Sample

The sample consists of the final set of peer-reviewed documents selected through a rigorous screening process. The initial search yielded 41 documents, and after screening for relevance and completeness, the final sample retained these 41 documents. This dataset serves as the representative sample of the global academic output, specifically linking "Problem-Based Learning" and "Higher-Order Thinking Skills" in Scopus.[43] The use of a focused, peer-reviewed database like Scopus ensures the reliability and high quality of the collected metadata for subsequent bibliometric analysis.[44,45]

Data Collection and Processing

The data collection and processing procedure was executed in a systematic, three-stage flow to ensure the validity and reliability of the final dataset, adhering to best practices in bibliometric research.[40]

Search Strategy and Data Retrieval

The literature search was conducted on February 23, 2025, exclusively within the Scopus database. The search strategy was formulated using a combination of controlled vocabulary and free-text terms relevant

to the research objectives, targeting the Article Title, Abstract, and Keywords (TITLE-ABS-KEY) fields to ensure maximum thematic coverage.[46] The precise Boolean search query implemented was: (TITLE-ABS-KEY ("problem-based learning" OR "PBL")) AND (TITLE-ABS-KEY ("higher order thinking skills" OR "HOTS")). This query explicitly linked the pedagogical method (PBL/PBL) with the desired cognitive outcome (HOTS/HOTS), ensuring that only documents discussing the nexus between the two concepts were retrieved.[44,45] This initial retrieval yielded 41 documents.

Bibliographic Screening and Refinement

The initial set of 41 documents underwent a rigorous screening and refinement process based on two sequential criteria:

Relevance Screening: the focus remained strictly on the intersection of the two core concepts, confirming the topical relevance of all 41 documents yielded by the initial Boolean search.

Metadata Completeness Screening: to maintain the high standard required for quantitative bibliometric mapping, each document was individually screened to verify the 100 % completeness of crucial metadata fields. These fields included: full author names, institutional affiliations, publication year, journal/source title, abstract, keywords, and citation counts.[46,47,48] Documents lacking complete information in any of these components were to be excluded; however, the verification process confirmed that all 41 documents possessed 100 % completeness across all tested components, thus maintaining the sample size.[49,50,51]

The entire set of 41 documents, confirmed for both thematic relevance and metadata completeness, was then downloaded in the standard .csv (Comma Separated Values) and .ris (Research Information Systems) formats for subsequent analysis.

Data Analysis and Visualization

The data analysis was primarily conducted using VOSviewer (version 1.6.20), a specialized software tool widely recognized for constructing and visualizing bibliometric networks.[47,52,53] This software was used to process the downloaded metadata and generate various network maps based on the eight key indicators derived from the research objectives:

Table 1. Indicators derived from the research objectives

Research Objective/Indicator	Analysis Type in VOSviewer	Description
Publication Trends	Annual Output Analysis	Descriptive statistics on the number of publications per year.
Leading Sources & Document Types	Descriptive Statistics	Frequency analysis of source titles (journals/conferences) and document type categories.
Disciplinary & Geographical Distribution	Network Analysis/ Descriptive Statistics	Frequency analysis of subject areas, countries, and affiliated institutions.
Keyword Analysis (Thematic Clusters)	Co-occurrence Analysis	Creating a network map based on the simultaneous appearance of author keywords to reveal thematic clusters.[41]
Author Collaboration Network	Co-authorship Analysis	Creating a network map based on the linkages between authors who co-wrote publications, revealing collaboration patterns.

Descriptive statistical analyses (e.g., frequencies, percentages) for publication trends, sources, and distributions were conducted directly on the dataset, while advanced network visualization (co-occurrence and co-authorship) was executed using VOSviewer's clustering algorithms.

Ethical Standards

As this research is classified as a non-observational bibliometric analysis, it exclusively uses publicly available metadata from published scientific literature, which are aggregated and anonymized for statistical purposes.[41] The study does not involve human subjects, personal data, intervention, or observation, and therefore, it is exempt from review by an Institutional Review Board (IRB). All data retrieval was conducted in compliance with the terms of service and access policies of the Scopus database.

Research Process Flowchart

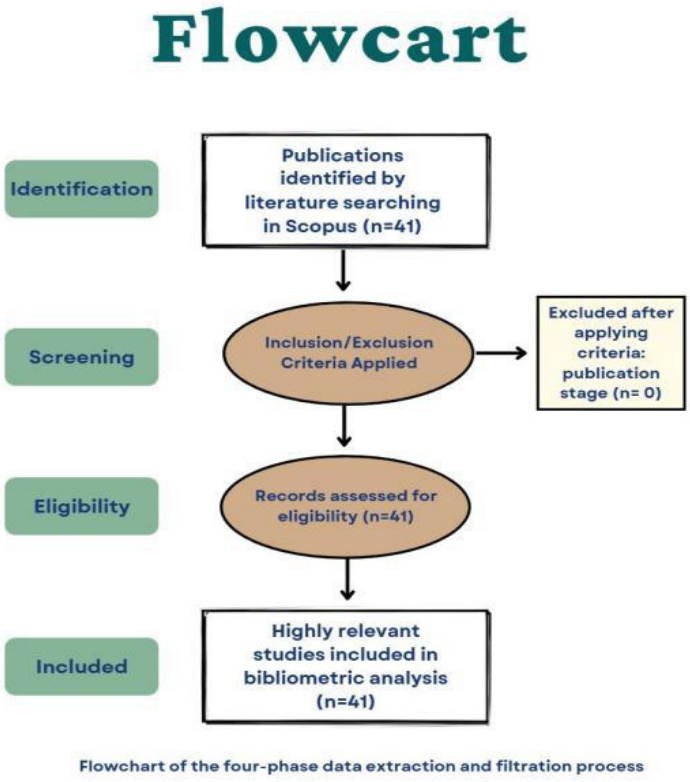

Figure 1. Flowchart[54]

The process began with data retrieval from the Scopus database using the keywords 'problem-based learning' OR 'PBL' AND 'higher-order thinking skills' OR 'HOTS' on the search date of February 23, 2025. This search stage yielded 41 documents, followed by a screening process based on topic relevance, document type, language, and metadata completeness. These documents then proceeded to the final selection stage, resulting in the same total of 41 documents. All selected documents were subsequently analyzed using bibliometric methods, covering publication trends, document types, publication sources, subject areas, institutions, countries, keywords, and author collaborations (co-authorship).[41,55,56]

RESULTS

This section meticulously presents the findings from the bibliometric analysis of 41 Scopus-indexed documents focusing on the intersection of Problem-Based Learning and Higher-Order Thinking Skills. The analysis systematically maps the research landscape across eight key dimensions: document yield, publication type distribution, annual trends, leading sources, disciplinary orientation, geographical and institutional contributions, keyword co-occurrence patterns, and author collaboration networks.

Document Retrieval and Filtering Process

The initial systematic search process conducted in the Scopus database, utilizing the complex combination of keywords 'problem-based learning' OR 'PBL' and 'higher-order thinking skills' OR 'HOTS,' yielded a modest but focused set of 41 documents. Following the application of specific inclusion and exclusion criteria primarily related to ensuring the documents were focused on higher education contexts, published in English, and contained complete metadata (author names, affiliations, keywords, and abstracts), all 41 initial documents were retained for the final analytical stage. This final set of 41 documents served as the definitive dataset for analyzing publication trends, subject area distribution, leading publication sources, author collaboration networks, and the intellectual structure of the PBL and HOTS research domain.

The relatively small size of this corpus (N=41) warrants a detailed examination of its composition, as it suggests a highly specific niche within the broader educational research field. This specificity is crucial; it implies that while general research on PBL and HOTS is vast, the specific application or conceptual coupling of these two constructs, as indexed and defined by the selected keywords, remains an area of nascent but growing

scholarly interest. The comprehensive metadata of this cohort of papers allows for a robust and granular analysis of the contributing elements shaping this particular research front.

Analysis of Document Type Distribution

The distribution of the 41 retrieved documents across different publication types provides initial insight into the stage and rigor of knowledge dissemination in this area.

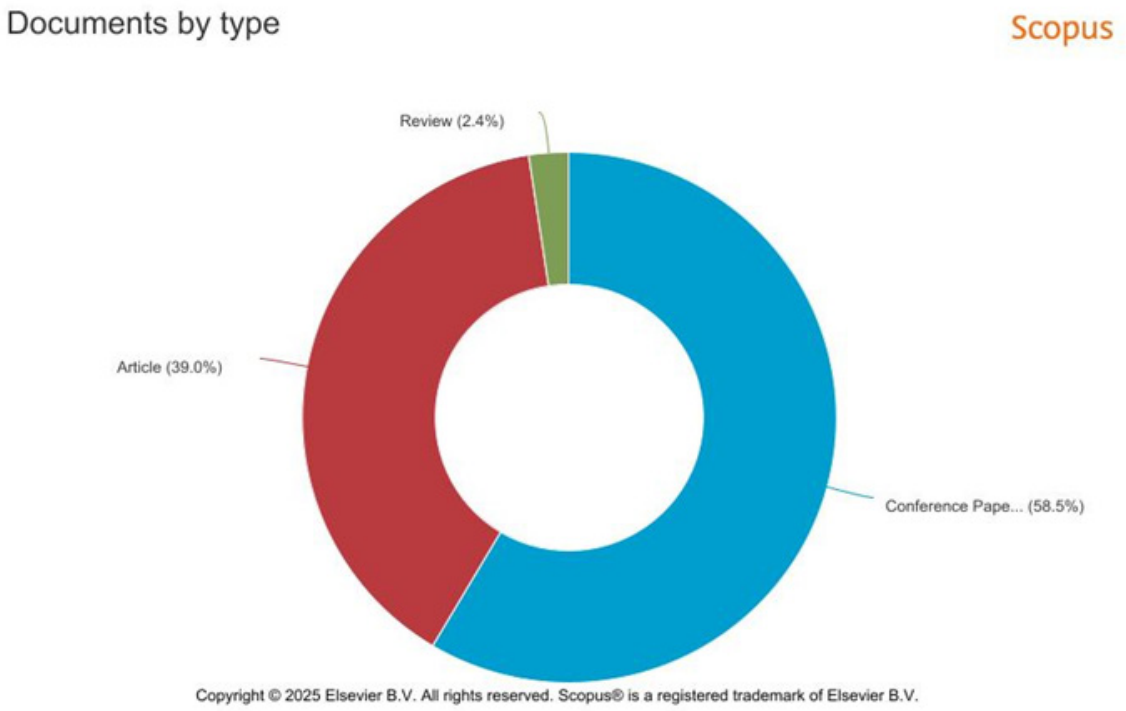

Figure 2. Distribution of Document Types[57]

The analysis revealed a dominant trend: Conference Papers constituted the largest proportion, representing 58,5 % of the total output. Journal Articles ranked second, making up 39,0 %, while Review Articles accounted for the smallest fraction, only 2,4 %. The dominance of Conference Papers is highly significant, suggesting a research domain characterized by a rapid dissemination of preliminary results, pedagogical innovations, and ongoing action research projects. Conference proceedings often serve as a platform for researchers, particularly those engaged in active teaching and curriculum experimentation, to quickly share early findings or localized case studies before they are formalized into peer-reviewed journal articles. The sheer volume of conference papers indicates that much of the knowledge creation in the PBL-HOTS nexus is occurring in forums designed for immediate feedback and scholarly dialogue, reflecting a community eager to share and test new approaches.

Conversely, Journal Articles (39,0 %) typically represent more mature research, having undergone a stringent, double-blind peer-review process, which usually translates to higher rigor, broader generalization, and more consolidated findings. The near-parity between conference papers and journal articles (though with the former slightly leading) suggests the field is in a transitional phase, moving from localized innovation to more formalized and theoretically grounded contributions. The slightly lower percentage of journal articles indicates a potential lag in the full crystallization of these conference findings into definitive, widely accepted scholarly literature.

The extremely low percentage of Review Articles (2,4 %) is perhaps the most telling finding regarding the field's current maturity level. Review articles, such as systematic reviews or meta-analyses, are essential for synthesizing existing knowledge, identifying theoretical gaps, and setting future research agendas. Their scarcity suggests that the intellectual landscape is still primarily focused on generating new empirical data rather than consolidating or summarizing existing knowledge. This highlights a clear opportunity for researchers to contribute comprehensive literature syntheses to help mature the field and provide a cohesive theoretical framework for the observed empirical trends.

Analysis of Annual Publication Trends

Tracing the publication output over time is essential for identifying periods of intellectual activity, stagnation, and growth, thereby linking scholarly output to global educational policy and pedagogical shifts.

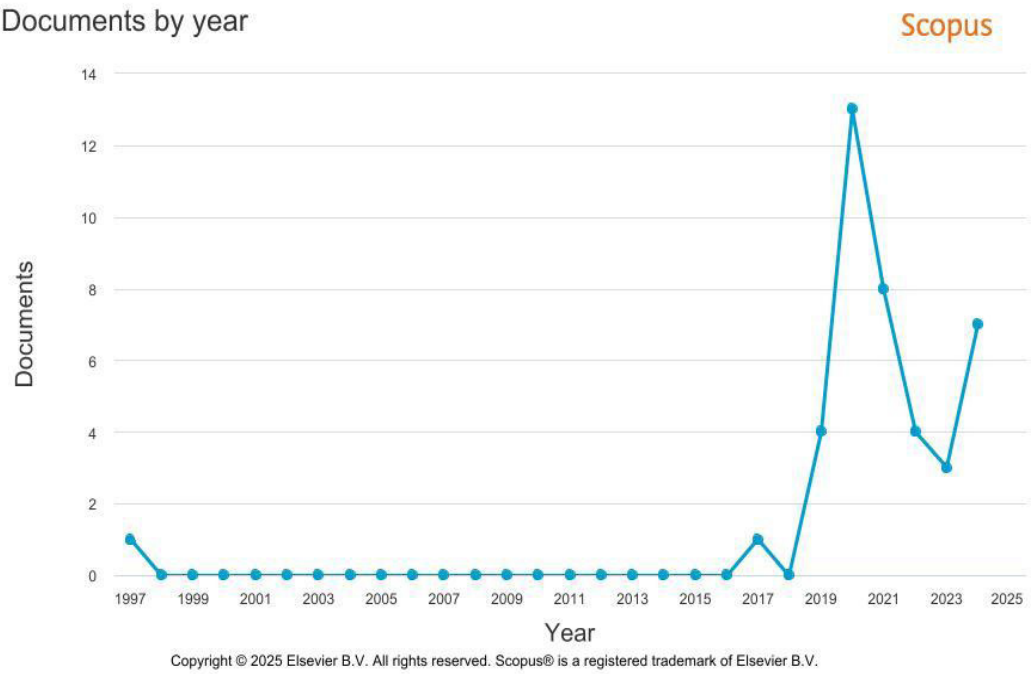

Figure 3. Publication Trends from 1997 to 2025[57]

The trend analysis spanning the period from 1997 to 2025 demonstrates a remarkable pattern of latency followed by explosive growth.

Period of Latency (1997–2018): for nearly two decades, academic attention to the direct relationship between PBL and HOTS was minimal. Only a single document was recorded in 1997, and another solitary document appeared in 2017. This low level of output suggests that while both PBL and HOTS existed as separate, well-established research domains, their explicit coupling and empirical investigation, as defined by the search query, were not a primary focus.

The Surge (2019): a significant upward trend commenced in 2019, which registered four publications. This sudden uptick marks a clear inflection point, potentially correlating with increased global emphasis on 21st-century skills and the push for pedagogical reforms designed to move education away from rote memorization toward cognitive complexity.

The Peak (2020): the volume of publications reached its apex in 2020, with a substantial output of 13 documents. This peak is not only statistically notable but is also temporally aligned with the most disruptive phase of the COVID-19 global pandemic. The necessity for rapid educational transformation, the pivot to online learning, and the urgent need to ensure continued cognitive skill development amidst institutional change likely drove a massive increase in pedagogical research, much of which focused on effective, asynchronous, and problem-centric models like PBL to foster higher-order thinking in remote settings.

Post-Peak Decline (2021–2023): following the dramatic peak, the publication rate gradually declined: eight in 2021, four in 2022, and three in 2023. This pattern is typical in bibliometrics, often representing the natural subsidence of scholarly activity after an intense period of crisis-driven research. As the immediate pressures of the pandemic stabilized and research energy was redirected, the initial high-volume output returned to a more sustainable level.

Projected Resurgence (2025): interestingly, the data for 2025 already indicates a resurgence, with seven publications recorded. Assuming this data is based on early indexing or projected acceptance rates, it signals a renewed, post-pandemic interest in consolidating the lessons learned and advancing the methodological integration of PBL and HOTS beyond reactive research. This suggests the topic has moved from a crisis-driven necessity to a stable, critical area of educational development.

In summary, the annual trend is not one of linear growth but of profound volatility, characterized by an extended period of dormancy followed by a concentrated period of intense scholarly activity, primarily centered around the global educational restructuring mandated by the pandemic era. The trajectory strongly indicates that the research field is now past its initial shock phase and is transitioning into a phase of deliberate, long-term development.

Analysis of Leading Publication Sources

Identifying the most frequently utilized publication sources helps to characterize the institutional and disciplinary homes for the research.

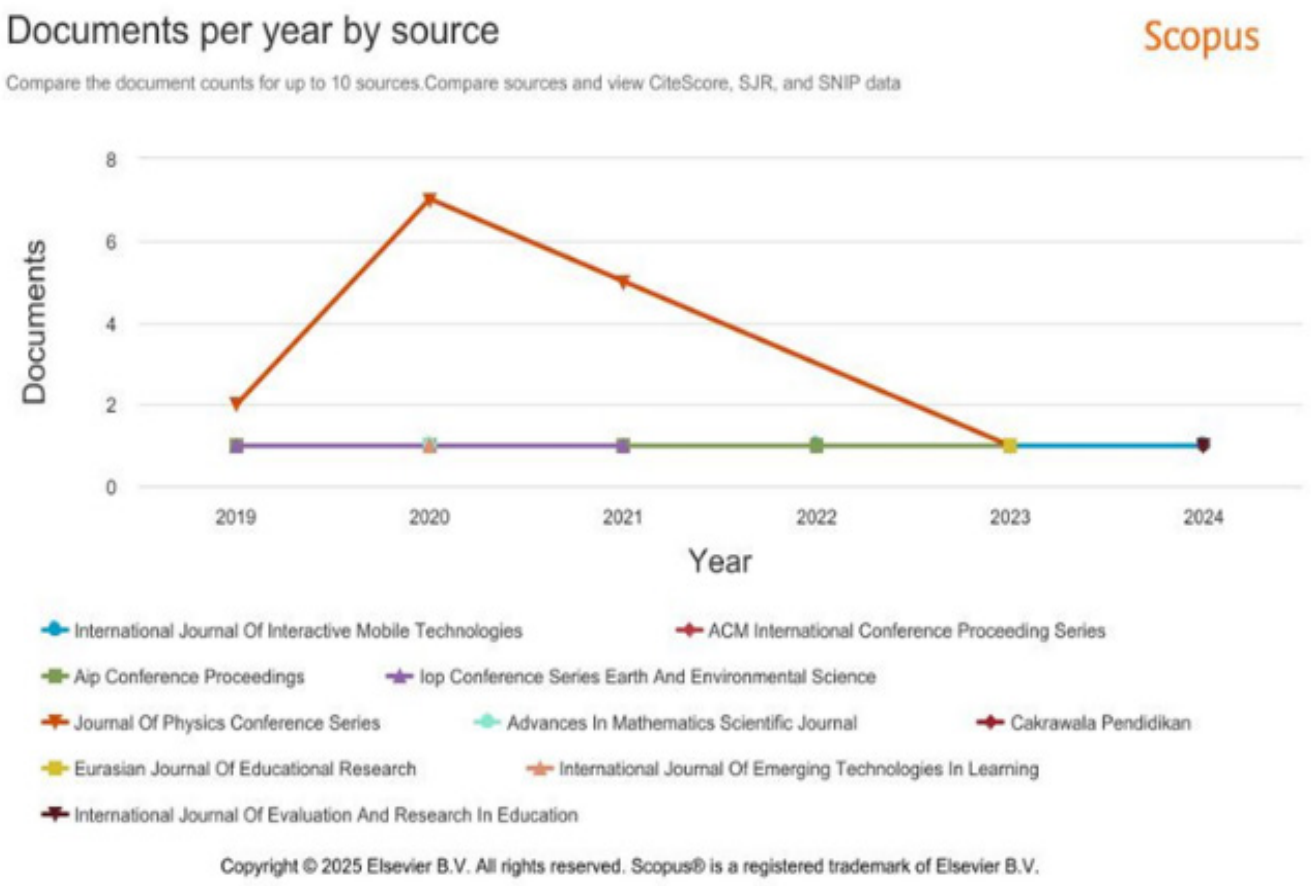

Figure 4. Distribution of Publications by Journal Sources[57]

The analysis revealed a pronounced concentration of output within a single source: The Journal of Physics: Conference Series. This series is overwhelmingly dominant, underscoring its role as the primary venue for disseminating research on PBL and HOTS within this corpus.

The high frequency of publications in this particular conference series, which operates under an Open Access model and specializes in proceedings across various scientific and technical domains, offers several critical insights:

STEM-centric Focus: the dominance immediately suggests that much of the empirical work linking PBL and HOTS is rooted in Science, Technology, Engineering, and Mathematics (STEM) education, particularly within physics education and related sciences. This aligns with the inherently problem-solving nature of these disciplines, where HOTS (analysis, evaluation, creation) is explicitly linked to conceptual mastery through problem-based instruction.

Proceedings as Primary Venue: as a conference series, this venue primarily publishes conference papers, which reinforces the earlier finding that a significant portion of this field's output is disseminated through rapid, early-stage publication formats.

Peak Alignment: crucially, the maximum contribution from this source—seven publications—occurred in 2020, perfectly aligning with the overall peak publication year. This confirms that the global surge in research during that year was largely channeled through large, high-volume conference proceedings, likely facilitated by the shift to online conference formats during the COVID-19 era.

The remaining contributions are scattered across a diverse, yet small, number of sources, including the International Journal of Interactive Mobile Technologies, ACM International Conference Proceeding Series, and various other journals and proceedings. This diversity, despite the small numbers, confirms that while a core group heavily utilizes a single proceedings venue, the topic is relevant across a wide spectrum of educational and technical fields, reflecting its interdisciplinary appeal.

Analysis of Research Subject Areas

The disciplinary classification of the documents reveals the thematic landscape where the PBL-HOTS connection is most actively researched and applied.

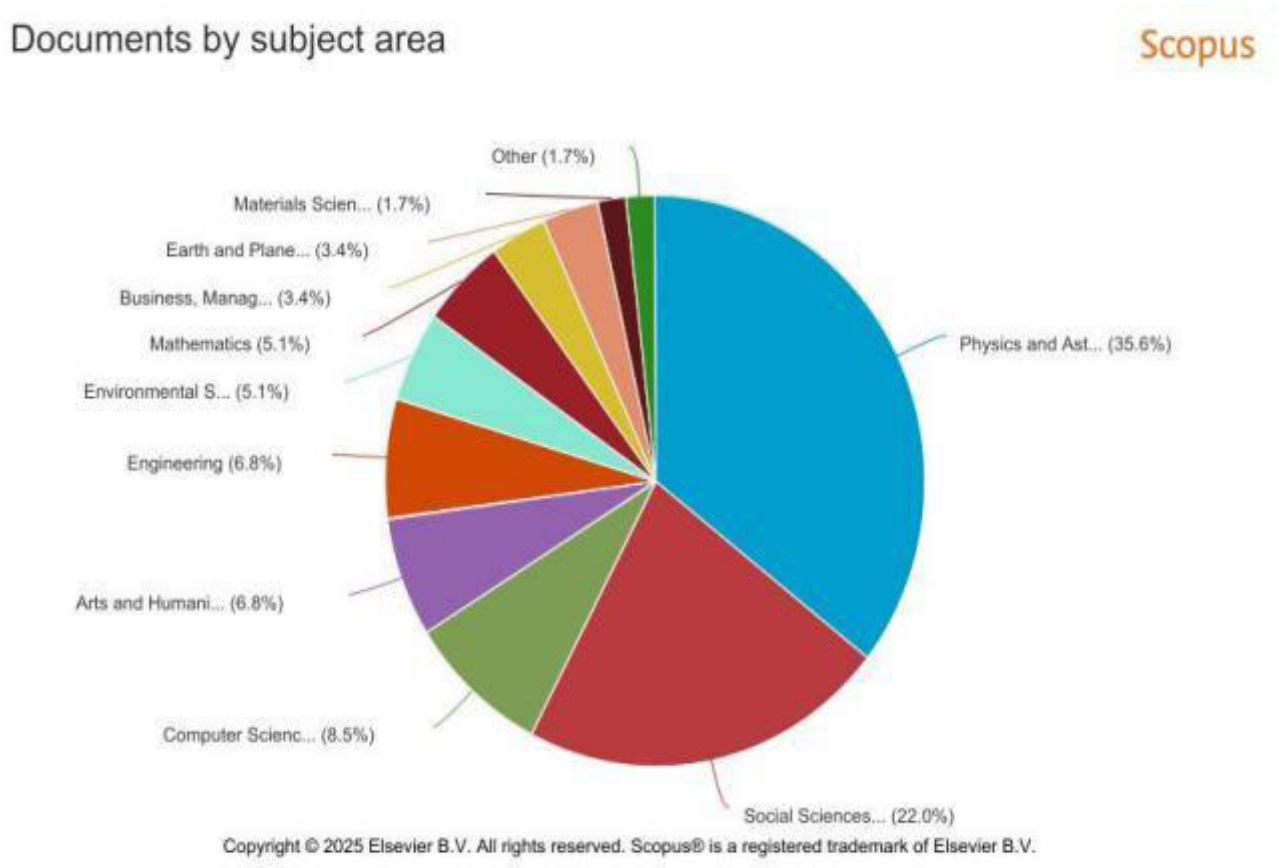

Figure 5. Distribution of Research Subject Areas[57]

The subject area distribution is profoundly multidisciplinary, yet shows a clear hierarchy of engagement:

Physics and Astronomy (35,6 %): this is the single largest subject area, closely correlating with the dominance of the Journal of Physics: Conference Series. This demonstrates that the highest volume of empirical studies on PBL and HOTS is concentrated in the physics education domain. The conceptual fit is strong: PBL, centered on complex physical or astronomical problems, naturally cultivates analytical, evaluative, and critical thinking skills required to solve those problems.

Social Sciences (22,0 %): ranking a strong second, the Social Sciences category represents the research that focuses on the pedagogical, psychological, and theoretical aspects of learning and instruction. This includes research on educational psychology, curriculum development, and educational innovation, providing the necessary theoretical and contextual grounding for why PBL is an effective mechanism for promoting HOTS in general.

Other STEM and Applied Fields: significant contributions come from Computer Science (8,5 %) and Engineering (6,8 %), reinforcing the theme that complex, ill-structured problem-solving inherent to these STEM fields is highly conducive to the PBL-HOTS framework.

Arts and Humanities (6,8 %) and Mathematics (5,1 %): these fields also show robust representation, indicating that the pedagogical utility of PBL and HOTS extends beyond the typical technical disciplines, finding effective application in subjects that require critical analysis of text, historical events, or abstract conceptual reasoning.

Minor Contributors: the remaining categories, such as Environmental Science (5,1 %), Business, Management, and Accounting (3,4 %), and Earth and Planetary Sciences (3,4 %), illustrate the broad applicability and interdisciplinary flexibility of the model.

In sum, the subject analysis confirms that the research activity is bipolar: rooted deeply in the empirical application within Physics Education, yet strongly supported by the Social Sciences, which provide the theoretical and methodological research frameworks.

Analysis of Geographical and Institutional Contributions

The geographical and institutional distribution reveals the global and regional centers of research excellence in this specific area.

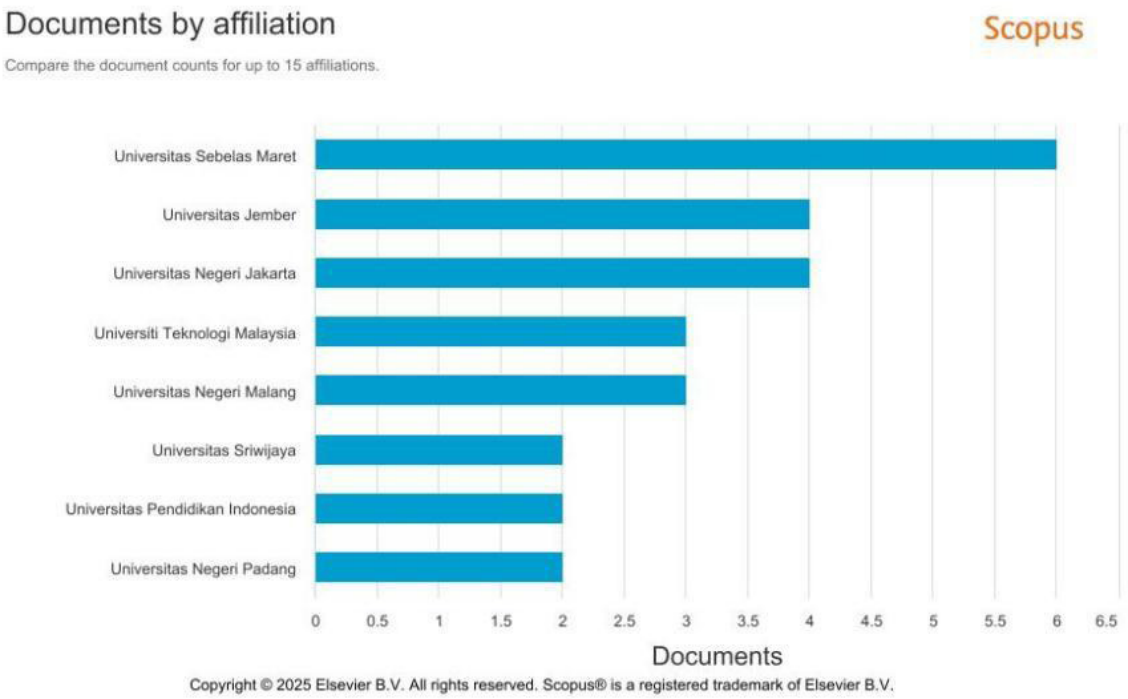

Figure 6. Distribution of Publications by Institutions[57]

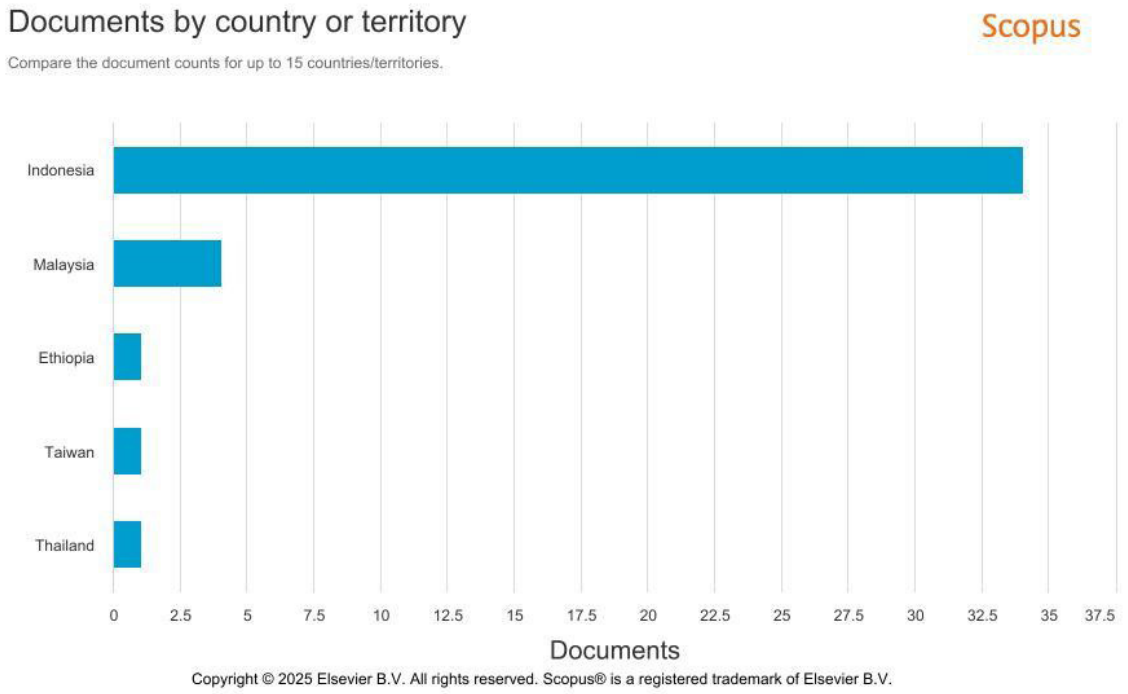

Figure 7. Distribution of Publications by Countries[57]

Geographically, the research is overwhelmingly concentrated in a specific region, demonstrating a clear center of gravity:

- Indonesia is the paramount contributor, accounting for approximately 34 publications the vast majority of the corpus. This underscores the intense national focus and institutional priority placed on integrating PBL and developing HOTS within the Indonesian educational system, likely driven by national education policies aimed at improving global competitiveness and aligning curricula with 21st-century skills standards.
- Malaysia ranks a distant second with around four publications, confirming the strong Southeast Asian regional dominance in this particular research niche.

- Other countries, including Ethiopia, Taiwan, and Thailand, show only marginal contributions, reinforcing the finding that the primary scholarly engine for this specific topic is localized within a few key Southeast Asian nations.

The institutional analysis provides a finer resolution of this national dominance:

Universitas Sebelas Maret is the most productive institution, generating six documents during the study period.

Universitas Jember and Universitas Negeri Jakarta occupy the subsequent positions, each contributing four documents.

Universiti Teknologi Malaysia and Universitas Negeri Malang both contributed three documents.

This pattern demonstrates that public universities, particularly in Indonesia, serve as the primary research hubs for developing and validating PBL and HOTS models. The presence of Universiti Teknologi Malaysia as a top-five contributor is crucial, as it highlights a shared, regional academic agenda regarding pedagogical innovation and educational quality improvement.

Keyword Co-occurrence and Intellectual Structure

The analysis of keyword co-occurrence, visualized through VOSviewer, is critical for mapping the intellectual structure and identifying the central thematic clusters driving the research.

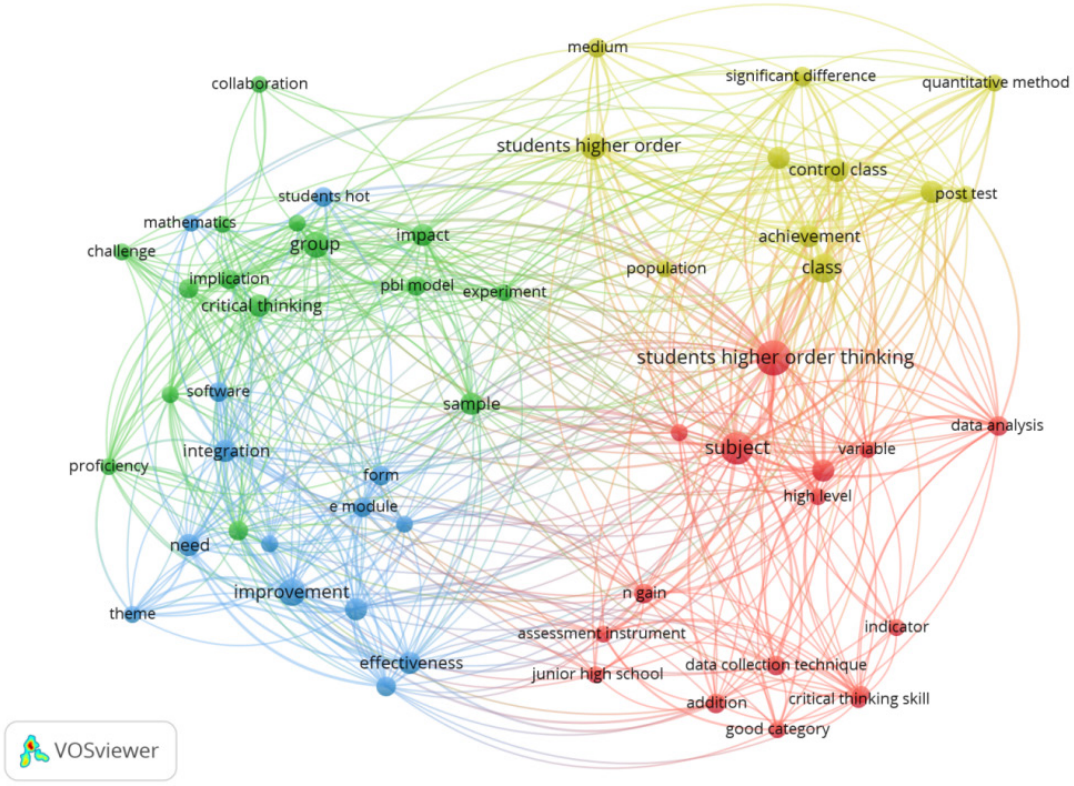

Figure 8. Keyword Co-occurrence Map in PBL and HOTS Research

The map reveals a highly interconnected, yet distinct, structure comprising four primary clusters:

Cluster 1 (Red: Assessment and Cognitive Core): this cluster focuses on the measurement and definition of cognitive outcomes, encompassing terms like students' higher-order thinking, critical thinking skills, and assessment instruments. This core cluster represents the fundamental research interest in how to define, measure, and validate the actual skills developed by students, emphasizing the need for robust evaluative tools.

Cluster 2 (Yellow: Methodology and Achievement): this cluster groups keywords related to research design and student success, including class, achievement, and quantitative methods. This highlights a strong methodological preference within the field, suggesting that many studies utilize quantitative, experimental, or quasi-experimental designs to establish a causal link between the PBL intervention and measurable student achievement outcomes.

Cluster 3 (Green: Application and Specific Subject Context): this cluster represents the practical

implementation of PBL, centered around terms like PBL model, critical thinking, and mathematics. This cluster demonstrates the importance of adapting the general PBL framework into specific instructional models and applying it effectively within disciplinary contexts, with mathematics being a key area of focus for this research cohort.

Cluster 4 (Blue: Technology and Innovation): this cluster is characterized by terms such as integration, improvement, and e-module. It signifies the emerging trend of integrating technological tools and digital resources (e-modules) into the PBL framework. This component of the research is directed toward leveraging technology to enhance the efficiency, accessibility, and effectiveness of PBL interventions, particularly in supporting the iterative improvement of learning methods.

The overall co-occurrence pattern confirms that the research on PBL and HOTS is driven by four interwoven thematic pillars: cognitive outcome assessment, quantitative methodology, subject-specific application, and technological enhancement.

Author Collaboration Network

The author's collaboration network visualization highlights the social structure of knowledge production, identifying prolific researchers and established partnerships.

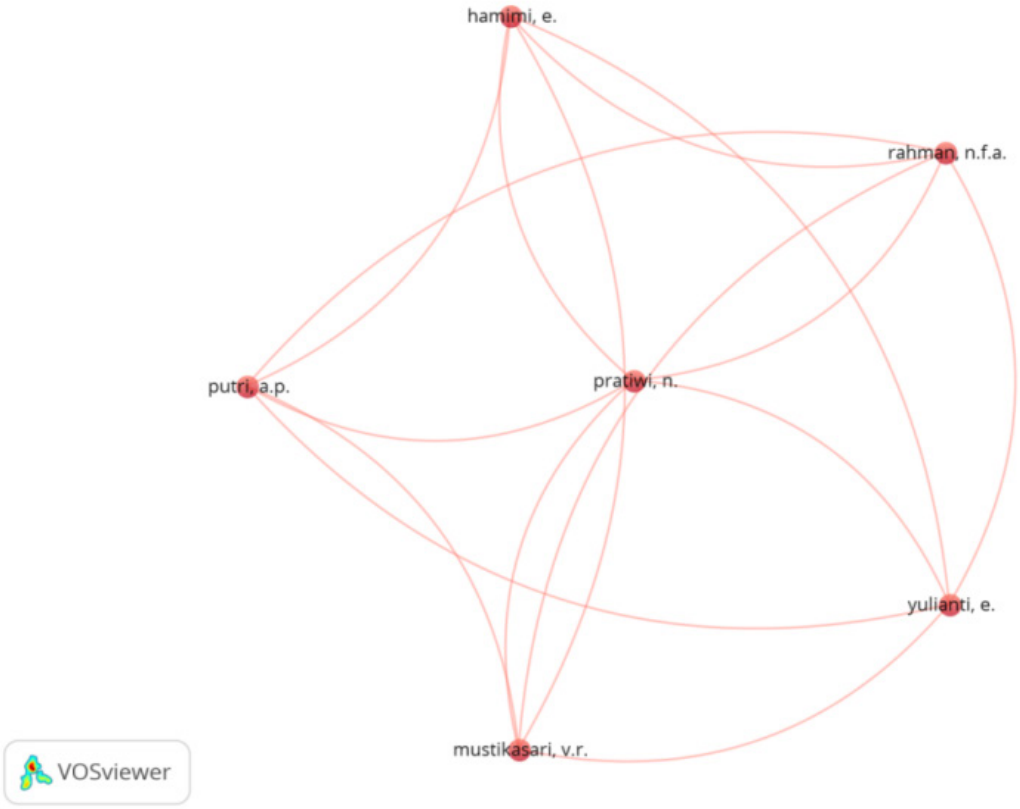

Figure 9. Author Collaboration Network in PBL and HOTS Research

The network analysis demonstrates that while the field is somewhat fragmented, a significant, tightly knit collaborative cluster exists. This group includes authors such as Pratiwi N., Hamdani E., Rahman N.F.A., Yulianti E., Mustikasari V.R., and Putri A.P. The visualization clearly shows Pratiwi N. serving as the central figure or hub, connecting all other authors within this largest collaboration network.

This pattern of strong, internal collaboration within a core group of researchers is highly characteristic of a developing research niche. Such consistent, long-term partnerships are vital for maintaining research continuity, ensuring the replication of methods, and building a cumulative body of evidence on the effectiveness and implementation strategies of PBL models designed to cultivate HOTS.

Analysis of Most Cited Articles

The examination of the ten most cited articles provides insight into the field's intellectual foundation, identifying the seminal works that have most heavily influenced subsequent research.

Table 2. Most Cited Articles on PBL and HOT

No	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
1	Cindy E. Hmelo et al.[12]	The Problem-Based Learning Tutorial: Cultivating Higher Order Thinking Skills	122	Journal for the Education of the Gifted (1997)	PBL effectively cultivates higher-order thinking by engaging students in problem-solving and reflection cycles. The approach encourages critical analysis, evaluation, and synthesis of knowledge, making it a powerful method for developing lifelong learning skills. Educators are recommended to integrate structured reflection into PBL tutorials to maximize its impact on students' reasoning and problem-solving abilities.
2	Suhirman et al.[5]	The Effect of Problem-Based Learning with Character Emphasis on Students' Higher-Order Thinking Skills and Characters	31	International Journal of Emerging Technologies in Learning (2020)	Problem-Based Learning (PBL) with character emphasis not only enhances students' higher-order thinking skills (HOTS) but also strengthens their character development. The integration of cognitive and affective aspects makes learning more holistic and impactful. It is recommended that educators embed explicit character values within PBL scenarios to simultaneously foster critical thinking and positive character formation.
3	SUPARMAN et al.[5]	Does Problem-Based Learning Enhance Students' Higher-Order Thinking Skills in Mathematics Learning?	25	ACM - ICBDE Conference (2021)	Meta-analysis results confirm that Problem-Based Learning (PBL) significantly improves students' higher-order thinking skills (HOTS) in mathematics. The approach promotes deeper conceptual understanding, critical reasoning, and problem-solving ability. It is recommended that mathematics educators adopt PBL strategies consistently to cultivate students' analytical and evaluative skills.
4	Sukatiman et al.[58,59]	Enhancing Higher-Order Thinking Skills in Vocational Education through Scaffolding-Problem-Based Learning	14	Open Engineering (2020)	The Scaffolding-PBL model effectively enhances vocational students' higher-order thinking skills (HOTS) across Bloom's taxonomy levels. Structured scaffolding within PBL supports learners in progressing from basic understanding to advanced critical and creative thinking. It is recommended that vocational educators integrate scaffolding strategies into PBL to systematically develop students' analytical, evaluative, and creative abilities.
5	Y. Yurniwati et al.[14]	Problem-based learning flipped classroom design for developing higher-order thinking skills during the COVID-19 pandemic in the geometry domain	13	Journal of Physics: Conference Series (2020)	Flipped PBL in geometry during COVID-19 improved students' HOTS by promoting active learning and problem-solving. Educators are encouraged to apply flipped-PBL models in remote or hybrid settings to strengthen higher-order thinking.
6	Liew Chuang Tong et al.[60]	Enhancing HOTS using Problem-Based Learning and Digital Games in the Context of Malaysian Primary Schools	8	International Journal of Interactive Mobile Technologies (2022)	Combining PBL with digital games effectively enhanced HOTS among Malaysian primary school students. Educators should integrate game-based elements into PBL to boost engagement and strengthen higher-order thinking.
7	Asri Widiatsih et al.[61]	The development of mathematical problems based on Higher Order Thinking Skill (HOTS) on comparative material by implementing PBL	8	Journal of Physics: Conference Series (2020)	PBL-based mathematical problems improved teachers' creative thinking and strengthened focus on HOTS in comparative material. It is recommended that teachers design PBL tasks emphasizing HOTS to enhance both instructional creativity and student outcomes. This approach can also serve as a model for developing subject-specific problem sets that foster higher-order thinking.

8	Hadi Suwono et al.[12]	Problem-based learning blended with online interaction to improve motivation, scientific communication, and higher-order thinking skills	8	AIP Conference Proceedings (2019)	Blended PBL with online interaction enhanced high school students' motivation, scientific communication, and higher-order thinking skills (HOTS). Educators are encouraged to adopt blended PBL models to foster active participation and collaborative learning. This design also provides flexibility in learning and supports the development of 21st-century competencies.
9	Harry Affandy et al.[62]	Integrating creative pedagogy into problem-based learning: The effects on higher-order thinking skills in science education	7	Thinking Skills and Creativity (2024)	Integrating creative pedagogy into PBL significantly enhanced students' higher-order thinking skills (HOTS) in science education. This approach fostered creativity alongside problem-solving, making learning more engaging and effective. Educators are recommended to embed creative strategies within PBL to simultaneously strengthen scientific reasoning and innovative thinking.
10	H. T. M. Silitonga et al.[63]	Problem-solving-based physics learning strategy to enhance students' higher-order thinking skills	6	Journal of Physics: Conference Series (2020)	A problem-solving-based physics learning strategy effectively improved students' higher-order thinking skills (HOTS) compared to traditional teaching methods. This approach encouraged deeper conceptual understanding, analytical reasoning, and application of physics principles. Educators are advised to adopt problem-solving strategies in science instruction to strengthen students' critical and creative thinking abilities.

The most influential work by far is Cindy E. Hmelo, Ferrari, "The Problem-Based Learning Tutorial: Cultivating Higher Order Thinking Skills," published in the Journal for the Education of the Gifted, which received 122 citations. As a cornerstone theoretical article from the field's earliest recognized period (1997), it establishes the foundational model: PBL fosters HOTS through iterative cycles of problem-solving and reflection, and its enduring influence confirms its status as the theoretical bedrock for this research domain.

The subsequent highly cited articles, while less dominant in citation count, reflect the evolving application and modification of the original model:

Suhirman, Muliadi, and Prayogi: this work, with 31 citations, introduced the concept of PBL with character emphasis, highlighting the influence of a holistic approach that simultaneously targets cognitive skills and affective, character development.

SUPARMAN, D JUANDI, M TAMUR: this article, cited 25 times, provided crucial meta-analytic evidence confirming the significant positive effect of PBL on HOTS specifically in the context of mathematics learning, solidifying the empirical case for its application in STEM disciplines.

Other highly cited studies demonstrate a focus on adapting PBL across diverse contexts and methodologies: Scaffolding-PBL in vocational education, Flipped Classroom models, the integration of Digital Games, and combining PBL with Online Interaction.

Collectively, the analysis of the most cited articles demonstrates two key elements: first, the enduring power of the foundational theoretical framework established by Hmelo and Ferrari; and second, the dynamic, adaptive nature of the contemporary research, which focuses on modifying the original PBL model through integration with technology, character education, and specific disciplinary scaffolding to maximize its impact on students' higher-order thinking skills. This entire body of work affirms that PBL is not a static model but a flexible and essential pedagogical approach consistently linked to the development of complex cognitive abilities.

DISCUSSION

Interpreting Publication Dynamics and Field Maturity

The findings of this bibliometric analysis illuminate the intellectual landscape and current maturity level of research, specifically coupling Problem-Based Learning and Higher-Order Thinking Skills. The corpus, although small with only 41 documents, provides a focused snapshot of scholarly activity. The most telling indicator of the field's developmental stage is the distribution of document types. The strong dominance of Conference Papers (58,5 %) over Journal Articles (39,0 %) suggests a research domain characterized by a high volume of rapid, preliminary knowledge dissemination.[58,59,64] Conference proceedings serve as crucial platforms for researchers, particularly those engaged in pedagogical action research or curriculum development, to quickly present early findings, innovative case studies, and localized implementations before they undergo the rigorous, lengthy peer-review required for formal journal publication. This implies that the scholarly community is highly focused on sharing practical experience and testing new PBL models in real-world educational settings..[49,50,51,65]

Conversely, the extremely low percentage of Review Articles (2,4 %) signals a significant gap in the field's intellectual consolidation. Review articles, such as systematic reviews or meta-analyses, are necessary to synthesize fragmented empirical results, identify prevailing theories, and define a cohesive research agenda.[12,66,67,68] Their scarcity indicates that the focus remains heavily on generating *new data* rather than consolidating existing knowledge, suggesting the field is still in an exploratory, nascent phase despite its increasing volume. This structural imbalance points to a clear, critical future research direction: the need for a comprehensive synthesis to mature the disciplinary core.[69]

Temporal Shifts and Contextual Drivers of Research

The analysis of publication trends reveals a history marked by prolonged latency followed by intense, concentrated growth, a pattern intrinsically linked to global educational reform and crisis. For nearly two decades (1997–2018), explicit research linking PBL and HOTS was sparse, indicating that while both concepts were individually researched, their deliberate empirical coupling was not a scholarly priority. The dramatic surge that peaked in 2020 (13 documents) is best interpreted as a direct response to two powerful global drivers. The first is the sustained, pre-pandemic global emphasis on 21st-century skills, which necessitates the use of pedagogical models, like PBL, designed to cultivate complex cognitive abilities (critical thinking, creativity, evaluation). The second, and more influential, is the COVID-19 pandemic. The mandatory global shift to remote and hybrid learning environments created an urgent need for instructional models that could effectively engage students asynchronously and center learning around complex, self-directed problem-solving. As a result, researchers rapidly documented the efficacy of adapted models such as the PBL flipped classroom[14] and blended PBL with online interaction.[70,71] The subsequent decline in 2021–2023 reflects the natural regression to the mean after the intense, crisis-driven research period, while the projected resurgence in 2025 indicates that the topic has secured its place as a stable and necessary area of ongoing pedagogical innovation.

The source analysis reinforces this contextual interpretation. The overwhelming dominance of the Journal of Physics: Conference Series suggests that the primary channel for documenting these rapid pedagogical responses and innovations was through large, high-volume conference proceedings, often organized to facilitate quick dissemination during the crisis. Furthermore, this concentration immediately ties the research to STEM education, where the problem-solving nature of the discipline, be it in physics, engineering, or mathematics, provides a fertile ground for the application of the PBL-HOTS model.[72,73,74,75]

Intellectual Structure and Methodological Framework

The co-occurrence map and citation analysis provide a robust picture of the intellectual architecture of this research field. Together, these two techniques co-occurrence mapping for visualizing thematic clusters and citation analysis for identifying foundational intellectual drivers are widely recognized as the most effective methodological combination for comprehensively mapping the conceptual landscape of a scholarly domain.[32,49,50,51]

The Enduring Theoretical Foundation

The intellectual core of the field remains firmly anchored in the seminal work by Hmelo[21], which serves as the most cited article (122 citations). This enduring relevance affirms that the theoretical mechanism proposed, where PBL cultivates HOTS through sustained cycles of problem-solving and structured reflection, is universally accepted as the fundamental premise.[39] Contemporary research, therefore, does not seek to overturn this principle, but rather to adapt, refine, and validate its implementation across new contexts.

This adaptive tendency is clearly reflected in recent highly cited studies, which focus on model modification.[5,58,59] For instance, the integration of character emphasis.[58,59] Demonstrates an expansion of the PBL model beyond purely cognitive outcomes to encompass affective and holistic student development. Similarly, the use of Scaffolding-PBL.[58,59] Highlights a crucial methodological refinement designed to support vocational students in traversing the cognitive complexity required for HOTS development, acknowledging that the original PBL model may require structural support for all learners.[76,77]

Thematic Research Agenda (Keyword Clusters)

The four keyword clusters effectively define the current research agenda:

Assessment and Cognitive Core: this cluster underscores the persistent methodological challenge: the need for reliable and valid *assessment instruments* capable of measuring non-rote skills like *critical thinking*. The field is actively working to move beyond simple achievement tests to develop nuanced tools that can accurately capture the transfer and application of HOTS.

Methodology and Achievement: the close relationship between *quantitative method* and *achievement* confirms a strong, prevailing positivist orientation. The majority of studies aim to empirically prove the causal efficacy of PBL interventions, lending robustness to the field's claim regarding PBL's effectiveness in boosting measurable learning outcomes.

Application and Subject Context: the explicit inclusion of *mathematics* and the *PBL model* in one cluster confirms the focus on disciplinary translation. Researchers are keen to demonstrate that PBL is not a generic teaching strategy but one that must be specifically tailored and validated for different subject requirements.[78,79,80,81]

Technology and Innovation: the cluster featuring *e-module* and *integration* reflects the post-pandemic imperative to modernize instruction. This area of research is focused on how digital tools can enhance the scalability, accessibility, and interactive components of PBL, making it viable for larger and more diverse student populations.[82,83,84]

Disciplinary Nexus

The concentration of studies in Physics and Astronomy (35,6 %) and Social Sciences (22,0 %) creates a bipolar disciplinary nexus. Physics education provides the context for application, where the complex, ill-structured nature of scientific problems offers an ideal setting for HOTS practice. Conversely, the Social Sciences contribute the necessary theoretical and methodological rigor, focusing on educational psychology, pedagogy, and curriculum design to understand why and how PBL works. This synergistic relationship is key to the field's advancement, ensuring that empirical findings (from STEM) are grounded in sound educational theory (from Social Sciences).

Geographical Context and Generalizability of Findings

The overwhelming geographical concentration in Indonesia (approx. 34 publications), reinforced by the institutional dominance of Indonesian universities, is the most crucial contextual finding of this study. This pattern strongly suggests that the research is primarily driven by national educational policy and local

institutional mandates aimed at elevating the quality of higher education and aligning it with global skill standards.

This regional bias has significant implications for the generalizability of the findings:

Context-Specificity: the accumulated empirical evidence largely reflects the effectiveness of PBL models within the Indonesian educational and cultural context. While the models themselves (e.g., Scaffolding-PBL, PBL with character emphasis) are innovative, their full efficacy may be tied to local factors such as curriculum structure, teacher training, and student background.

Implication for Policymakers: for policymakers and curriculum developers in Indonesia, the data provide a strong validation of their investment in PBL as a central strategy for HOTS improvement. The established author collaboration networks further indicate sustained local capacity for self-improvement and evidence-based curriculum reform.

Need for Comparative Studies: for the international research community, the data highlights a major gap. The low output from Europe, North America, and other Asian regions (as represented by this Scopus corpus) necessitates comparative research. Future studies should explicitly seek to test these successful Southeast Asian PBL models in vastly different cultural and educational settings to establish external validity and broader theoretical applicability.

Limitations and Future Research Directions

This bibliometric analysis successfully mapped the research on PBL and HOTS, confirming its rapid growth phase, its strong disciplinary grounding in STEM and Social Sciences, and its profound regional focus. The field is theoretically stable and actively engaged in methodological innovation, particularly regarding technological integration and rigorous quantitative validation.

However, this study has limitations. Relying solely on the Scopus database and English-language publications inherently excludes valuable research, particularly that published in national or local journals outside the major indices. This limitation likely contributes to the observed geographical bias, potentially underrepresenting scholarly work from other regions published in their local languages.

Based on these findings, future research should pursue three critical directions:

Systematic Synthesis: given the scarcity of review articles, the academic community should prioritize conducting systematic literature reviews and meta-analyses to consolidate the fragmented evidence, establish a consensus on the most effective PBL modifications, and formalize the theoretical mechanisms linking PBL to specific HOTS components.

Methodological Diversification: while the quantitative focus is strong, future work should integrate mixed-methods or robust qualitative designs to delve into the *processes* of cognitive engagement, student reflection, and instructor-student interaction that mediate the success of PBL in fostering HOTS, thereby providing deeper explanatory power beyond mere outcome measurement.

Global Comparative Studies: to overcome the existing geographical bias, researchers must engage in international collaboration to conduct comparative studies that test the efficacy of the innovative PBL models developed in Indonesia and Malaysia within diverse global contexts, thus advancing the theory of PBL-HOTS from a context-specific application to a globally validated pedagogical principle.

CONCLUSIONS

This study successfully mapped the research landscape connecting Problem-Based Learning and Higher-Order Thinking Skills in higher education through a systematic bibliometric analysis of 41 Scopus-indexed documents from 1997 to 2025. The analysis reveals a research field characterized by a high output of Conference Papers and a sharp increase in publications in 2020, affirming the model's relevance during the global shift toward digital and blended learning. The geographical distribution is heavily localized, with Indonesia emerging as the main contributor, establishing its public universities as the key centers for research and validation in this area. Intellectually, the field is firmly rooted in the foundational theory established by the most cited article by Hmelo[12] but recent efforts are focused on rigorous quantitative validation and model adaptation, especially through the integration of technology and subject-specific modifications. This study offers a comprehensive structural map of the field and confirms the effectiveness of PBL as an adaptable teaching strategy for developing HOTS, especially within STEM and Southeast Asian contexts. However, the findings point to a critical need for future research to go beyond a regional focus by engaging in international comparative studies, diversifying methods beyond quantitative approaches, and emphasizing systematic synthesis to consolidate the quickly growing body of empirical evidence.

BIBLIOGRAPHIC REFERENCES

1. Iswari M, Afdal A, Nurhastuti N, Syahputra Y, Ismail RN. Validation of Career Planning Instrument for Deaf (CPID): Rasch Model Analysis. In: AIP Conference Proceedings. AIP Publishing; 2023.

2. Santandreu Calonge D, Aman Shah M, Riggs K, Connor M. MOOCs and upskilling in Australia: A qualitative literature study. Cogent Educ. 2019;6(1):1687392.

3. Snoswell A, Osman K, Witzenberger K, Mitchell P, Goldenfein J, Riedlinger M. DMRC Response to Jobs and Skills Australia call for input:"Have Your Say on Gen AI." 2025;

4. Ismail RN, Fauzan A. Exploring Self-Regulated Learning and Their Impact on Students' Mathematical Communication Skills on the Topic of Number Patterns With the Blended Learning System. J High Educ Theory Pract. 2023;23(16).

5. Suhirman Y, Muliadi A, Prayogi S. The effect of problem-based learning with character emphasis toward students' higher-order thinking skills and characters. Int J Emerg Technol Learn. 2020;15(6):183–91.

6. Dewa BH, Zaim M. The Implementation of Problem Based Learning in Teaching English At Grade X SMK 04 Kepahiang, Bengkulu, Indonesia. In: AIP Conference Proceedings. 2023. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85176724331&doi=10.1063%2F5.0148372&partnerID=40&md5=72566451c42f4fde8027b5cc293eb7a1

7. Ismail RN, Arnawa IM. Improving StudentsReasoning and Communication Mathematical Ability by Applying Contextual Approach of The 21st Century at A Junior High School In Padang. In: 2nd International Conference on Mathematics and Mathematics Education 2018 (ICM2E 2018). Atlantis Press; 2018. p. 144–9.

8. Liana P, Liberty IA, Murti K, Hafy Z, Salim EM, Zulkarnain M, et al. A systematic review on neutrophil extracellular traps and its prognostication role in COVID-19 patients. Immunol Res. 2022;70(4):449–60.

9. Liana D, Phanumartwiwath A. Leveraging knowledge of Asian herbal medicine and its active compounds as COVID-19 treatment and prevention. J Nat Med. 2022;76(1):20–37.

10. Widyawati L. Measurement concerns and agreement of environmental social governance ratings. Account Financ. 2021;61:1589–623.

11. Thahir M, Komariah A, Kurniady DA, Suharto N, Kurniatun TC, Widiawati W, et al. Professional development and job satisfaction on teaching performance. Linguist Cult Rev. 2021;5(S4):2507–22.

12. Hmelo CE, Ferrari M. The problem-based learning tutorial: Cultivating higher order thinking skills. J Educ Gift. 1997;20(4):401–22.

13. Ismail RN, Fauzan A, Arnawa IM. Analysis of student learning independence as the basis for the development of digital book creations integrated by realistic mathematics. In: Journal of Physics: Conference Series. IOP Publishing; 2021. p. 12041.

14. Yurniwati Y, Utomo E. Problem-based learning flipped classroom design for developing higher-order thinking skills during the COVID-19 pandemic in geometry domain. J Phys Conf Ser. 2020;1663(1).

15. Yustina Y, Halim L, Mahadi I. The effect of'fish diversity'book in Kampar district on the learning motivation and obstacles of Kampar High School students through online learning during the Covid-19 period. J Innov Educ Cult Res. 2020;1(1):7–14.

16. Ismail RN, Fauzan A, Yerizon. Analysis of students' motivation and self-regulation profiles in online mathematics learning junior high school at Padang city. In: AIP Conference Proceedings. AIP Publishing LLC; 2023. p. 60025.

17. Loyens SMM, Magda J, Rikers RMJP. Self-directed learning in problem-based learning and its relationships with self-regulated learning. Educ Psychol Rev. 2008;20(4):411–27.

18. Loyens SMM, Rikers RMJP, Schmidt HG. Relationships between students' conceptions of constructivist learning and their regulation and processing strategies. Instr Sci. 2008;36(5):445–62.

19. Ismail RN, Mudjiran N. Membangun karakter melalui Implementasi Teori Belajar behavioristik pembelajaran matematika berbasis kecakapan abad 21. Menara Ilmu J Penelit dan Kaji Ilm. 2019;13(11).

20. Tan CL, Zakaria R. Muhammad Nur Syafiq Mohamad Ismail1, 2, Muhammad Aiman Saufi Ahmad Fahri2. Sci Rep. 2025;15:6.

21. Hmelo-Silver CE. Problem-based learning: What and how do students learn? Educ Psychol Rev. 2004;16(3):235–66.

22. Choy MSK. Delete Tm Approach, The: Designing Errors For Learning And Teaching. World Scientific; 2023.

23. Garcia A. Facilitated Video Case-Based Learning: An Exploratory Single-Case Study of Paramedic Workplace Learning. Sam Houston State University; 2025.

24. MUNDHE DRE. The Nexus of Ideas. 2025;

25. Yerizon I, Ismail RN. Improving Student's Mathematical Communication Skills Through Mathematics Worksheet Based on Realistic Mathematics Education. 2020;

26. Oktadela R, Gistituati N, Amri Z. Developing problem based learning / PBL model based on character. Int J Sci Technol Res. 2020;9(3):4165–7. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85082525449&partnerID=40&md5=015c9a56895ad3a26b7ed8e86b183ddb

27. Oktadela R, Gistituati N, Amri Z. Developing A Problem-Based Learning/PBL Model for Improve Students' English Speaking Problem Solving Ability and Self Confidence at Economic Department of University. In: Journal of Physics: Conference Series. 2019. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85076388924&doi=10.1088%2F1742-6596%2F1387%2F1%2F012045&partnerID=40&md5=6bde73ee4aa074de6f7325b32a5f8413

28. Syarifuddin H, Riza Y, Harisman Y, Ismail RN. Students' Response to the Use of a Flipped Learning Model (FLM) in Abstract Algebra Course. In: Unima International Conference on Social Sciences and Humanities (UNICSSH 2022). Atlantis Press; 2023. p. 1435–41.

29. Yusof N, Rosidi SA, Ibrahim NK, Ali AEB. Thematic textual hadith classification: An experiment in rapidminer using support vector machine (SVM) and naïve bayes algorithm. Int J. 2020;9(4).

30. Dolmans DE, Fukumura D, Jain RK. Photodynamic therapy for cancer. Nat Rev cancer. 2003;3(5):380–7.

31. Fathira V. Relationship between Emotional Intelligence and Multiple Literacy among Secondary School Students in the Socio-Technological Transformation Era. Salud, Cienc y Tecnol. 2025;5. https://www.scopus.com/inward/record.uri?eid=2-s2.0-105013864262&doi=10.56294%2Fsaludcyt20251802&partnerID=40&md5=248ef0150c7b54a9f83ad020000ac780

32. Zupic I, Čater T. Bibliometric methods in management and organization. Organ Res methods. 2015;18(3):429–72.

33. Daim TU, Rueda G, Martin H, Gerdsri P. Forecasting emerging technologies: Use of bibliometrics and patent analysis. Technol Forecast Soc Change. 2006;73(8):981–1012.

34. Borgman CL. Research Data: Who will share what, with whom, when, and why? 2010;

35. Borgman CL. The conundrum of sharing research data. J Am Soc Inf Sci Technol. 2012;63(6):1059–78.

36. Borgman CL. The digital future is now: A call to action for the humanities. Digit Humanit Q. 2010;3(4).

37. Borgman CL. Big data, little data, no data: Scholarship in the networked world. MIT press; 2017.

38. Callon M, Courtial JP, Turner WA, Bauin S. From translations to problematic networks: An introduction to co-word analysis. Soc Sci Inf. 1983;22(2):191–235.

39. Garfield E. Is citation analysis a legitimate evaluation tool? Scientometrics. 1979;1(4):359–75.

40. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. J Bus Res. 2021;133:285–96.

41. Moral-Muñoz JA, Herrera-Viedma E, Santisteban-Espejo A, Cobo MJ. Software tools for conducting bibliometric analysis in science: An up-to-date review. Prof la Inf. 2020;29(1).

42. Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. J Informetr. 2017;11(4):959–75.

43. Fahimnia B, Sarkis J, Davarzani H. Green supply chain management: A review and bibliometric analysis. Int J Prod Econ. 2015;162:101–14.

44. Harzing AW, Alakangas S. Microsoft Academic: is the phoenix getting wings? Scientometrics. 2017;110(1):371–83.

45. Harzing AW, Alakangas S. Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. Scientometrics. 2016;106(2):787–804.

46. Chinchilla-Rodríguez Z, Miguel S, Perianes-Rodríguez A, Ovalle-Perandones MA, Olmeda Gómez C. Autonomy vs. dependency of scientific collaboration in scientific performance. 2016;

47. Van Eck NJ, Waltman L. Visualizing bibliometric networks. In: Measuring scholarly impact: Methods and practice. Springer; 2014. p. 285–320.

48. Waltman L, Van Eck NJ, Noyons ECM. A unified approach to mapping and clustering of bibliometric networks. J Informetr. 2010;4(4):629–35.

49. Cobo MJ, López-Herrera AG, Herrera-Viedma E, Herrera F. An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the Fuzzy Sets Theory field. J Informetr. 2011;5(1):146–66.

50. Cobo A, Garrido N, Crespo J, José R, Pellicer A. Accumulation of oocytes: a new strategy for managing low-responder patients. Reprod Biomed Online. 2012;24(4):424–32.

51. Cobo MJ, López-Herrera AG, Herrera-Viedma E, Herrera F. Science mapping software tools: Review, analysis, and cooperative study among tools. J Am Soc Inf Sci Technol. 2011;62(7):1382–402.

52. Van Eck NJ, Waltman L. CitNetExplorer: A new software tool for analyzing and visualizing citation networks. J Informetr. 2014;8(4):802–23.

53. Ruiz-Castillo J. The comparison of classification-system-based normalization procedures with source normalization alternatives in Waltman and Van Eck (2013). J Inf. 2014;8(1):25–8.

54. Gusteti MU, Musdi E, Dewata I, Rasli AM. European Journal of Educational Research. Eur J Educ Res. 2025;14(3):723–41.

55. Muñoz JAM, Viedma EH, Espejo ALS, Cobo MJ. Software tools for conducting bibliometric analysis in science: An up-to-date review. El Prof la Inf. 2020;29(1):4.

56. Velez-Estevez A, García-Sánchez P, Moral-Muñoz JA, Cobo MJ. Why do papers from international collaborations get more citations? A bibliometric analysis of Library and Information Science papers. Scientometrics. 2022;127(12):7517–55.

57. Rossa R. Scopus. https://www.scopus.com

58. Sukatiman S, Akhyar M, Siswandari, Roemintoyo. Enhancing higher-order thinking skills in vocational education through scaffolding-problem based learning. Open Eng. 2020;10(1):612–9.

59. Sukatiman S, Roemintoyo R, Akhyar M, Sutikno S, Suwarno S. Kolaborasi guru-dosen dalam penelitian

tindakan kelas untuk meningkatkan hasil belajar siswa. SCAFFOLDING J Pendidik Islam dan Multikulturalisme. 2020;2(2):82–92.

60. Tong LC, Rosli MS, Saleh NS. Enhancing HOTS using Problem-Based Learning and Digital Game in the Context of Malaysian Primary School. Int J Interact Mob Technol. 2022;16(2):101–12.

61. Widiatsih A, Wardani DAR, Royhana U, Djamali F, Septory BJ. The development of mathematical problem based on Higher Order Thinking Skill (HOTS) on comparative material by implementing PBL and its effect on the teacher's creative thinking skill. J Phys Conf Ser. 2020;1538(1).

62. Affandy H, Sunarno W, Suryana R, Harjana. Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. Think Ski Creat. 2024;53(December 2023):101575.

63. Silitonga HTM, Panjaitan M, Supriyati Y. Problem solving based physics learning strategy to enhance students' higher order thinking skills. J Phys Conf Ser. 2020;1567(4).

64. Gingras Y. Bibliometrics and research evaluation: Uses and abuses. Mit Press; 2016.

65. Arnellis A, Syarifuddin H, Ismail RN. Optimizing students' mathematical critical and creative thinking skills through the flip-a-team model with e-learning. Al-Jabar J Pendidik Mat. 2023;14(1):133–40.

66. Freschet GT, Pagès L, Iversen CM, Comas LH, Rewald B, Roumet C, et al. A starting guide to root ecology: strengthening ecological concepts and standardising root classification, sampling, processing and trait measurements. New Phytol. 2021;232(3):973–1122.

67. Garnier P, Viquerat J, Rabault J, Larcher A, Kuhnle A, Hachem E. A review on deep reinforcement learning for fluid mechanics. Comput Fluids. 2021;225:104973.

68. Guler SA, Ebner L, Aubry-Beigelman C, Bridevaux PO, Brutsche M, Clarenbach C, et al. Pulmonary function and radiological features 4 months after COVID-19: first results from the national prospective observational Swiss COVID-19 lung study. Eur Respir J. 2021;57(4).

69. Kuhn HG, Dickinson-Anson H, Gage FH. Neurogenesis in the dentate gyrus of the adult rat: age-related decrease of neuronal progenitor proliferation. J Neurosci. 1996;16(6):2027–33.

70. Suwono H, Dewi EK. Problem-based learning blended with online interaction to improve motivation, scientific communication and higher order thinking skills of high school students. AIP Conf Proc. 2019;2081.

71. DEWI IS, Hastuti US, Lestari U, SUWONO H. Microbiological Quality Profile, Protein Content, and Organoleptic Quality of Nile Tilapia Wadi, a Traditional Fermented Food from Central Kalimantan. J Asian Microbiol Biotech Env Sc. 2019;21(4).

72. Silitonga PES, SE MM. Peningkatan kinerja SDM melalui motivasi, kepemimpinan, komitmen, dan lingkungan kerja. Penebar Media Pustaka; 2020.

73. Rizwanul Fattah IM, Ong HC, Mahlia TMI, Mofijur M, Silitonga AS, Rahman SMA, et al. State of the art of catalysts for biodiesel production. Front Energy Res. 2020;8:101.

74. Silitonga KAA, Ahmad F, Simanjuntak CW, Atrizka D. Exploring the nexus between the HR practices and work engagement: The mediating role of Job Demand. Syst Rev Pharm. 2020;11(7):342–51.

75. Mahlia TMI, Syazmi Z, Mofijur M, Abas AEP, Bilad MR, Ong HC, et al. Patent landscape review on biodiesel production: Technology updates. Renew Sustain Energy Rev. 2020;118:109526.

76. Kirschner P, Sweller J, Clark RE. Why unguided learning does not work: An analysis of the failure of discovery learning, problem-based learning, experiential learning and inquiry-based learning. Educ Psychol. 2006;41(2):75–86.

77. Van den Bossche P, Gijselaers WH, Segers M, Kirschner PA. Social and cognitive factors driving teamwork in collaborative learning environments: Team learning beliefs and behaviors. Small Gr Res. 2006;37(5):490–521.

78. Nugraha T, Suparman S. Heterogeneity of Indonesian primary school students' mathematical critical thinking skills through problem-based learning: A meta-analysis. Al-Jabar J Pendidik Mat. 2021;12(2):315–28.

79. Suparman DJ, Tamur M. Problem-based learning for mathematical critical thinking skills: A meta-analysis. J Hunan Univ Nat Sci. 2021;48(2).

80. Suparman S, Yohannes Y, Arifin N. Enhancing mathematical problem-solving skills of Indonesian junior high school students through problem-based learning: a systematic review and meta-analysis. Al-Jabar J Pendidik Mat. 2021;12(1):1–16.

81. Suparman S, Juandi D, Tamur M. Does Problem-Based Learning Enhance Students' Higher Order Thinking Skills in Mathematics Learning? A Systematic Review and Meta-Analysis. ACM Int Conf Proceeding Ser. 2021;44–51.

82. Yang W, Du H, Liew ZQ, Lim WYB, Xiong Z, Niyato D, et al. Semantic communications for future internet: Fundamentals, applications, and challenges. IEEE Commun Surv Tutorials. 2022;25(1):213–50.

83. Rossing P, Caramori ML, Chan JCN, Heerspink HJL, Hurst C, Khunti K, et al. Executive summary of the KDIGO 2022 Clinical Practice Guideline for Diabetes Management in Chronic Kidney Disease: an update based on rapidly emerging new evidence. Kidney Int. 2022;102(5):990–9.

84. Rossing P, Caramori ML, Chan JCN, Heerspink HJL, Hurst C, Khunti K, et al. KDIGO 2022 clinical practice guideline for diabetes management in chronic kidney disease. Kidney Int. 2022;102(5):S1–127.

FINANCING

The authors did not receive financing for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Rona Rossa, M. Zaim, Mukhaiyar.
Data curation: Rona Rossa.
Formal analysis: Rona Rossa, M. Zaim.
Research: Rona Rossa.
Methodology: Rona Rossa, M. Zaim.
Project management: Rona Rossa, M. Zaim.
Resources: M. Zaim, Mukhaiyar.
Software: Rona Rossa.
Supervision: M. Zaim, Mukhaiyar.
Validation: M. Zaim, Mukhaiyar.
Display: Rona Rossa.
Drafting - original draft: Rona Rossa.
Writing - proofreading and editing: Rona Rossa, M. Zaim, Mukhaiyar.