

Mapping Global Research Trends on Problem-Based Learning Integrated with STEM and Artificial Intelligence in Education: A Bibliometric Analysis

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Abstract

This study presents a bibliometric analysis of global research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. Although previous studies have separately explored STEM education, problem-solving skills, and AI-supported learning, limited research has systematically mapped the convergence of PBL, STEM, and AI within a unified educational framework. Therefore, this study aims to analyse publication trends, influential contributors, and thematic developments within this emerging interdisciplinary field. Data were retrieved from the Scopus database using a PRISMA-guided search strategy, resulting in 477 publications included in the final analysis. Bibliometric indicators were generated using biblioMagika®, while OpenRefine and VOSviewer supported data harmonisation and visualisation. The findings reveal substantial growth in publication productivity, particularly after 2014, indicating increasing scholarly attention towards PBL integrated with STEM and AI. The United States emerged as the leading contributor in publication output and citation influence. Co-occurrence analysis identified major thematic clusters related to active learning, engineering education, critical thinking, collaboration, educational technology, and artificial intelligence. Overall, this study contributes to the understanding of the intellectual structure and evolving research landscape of PBL integrated with STEM and AI in education while highlighting emerging directions for future research.

Keywords: Problem-Based Learning, STEM Education, Artificial Intelligence, Bibliometric Analysis

Introduction

In recent years, educational research has increasingly emphasised learner-centred pedagogies and technology-enhanced learning approaches in preparing students for the challenges of the twenty-first century. The rapid advancement of Science, Technology, Engineering, and Mathematics (STEM) education, together with the growing influence of Artificial Intelligence (AI), has transformed teaching and learning practices across multiple educational contexts (Li et al., 2022; Bond et al., 2024). Within this transformation, Problem-Based Learning (PBL) has gained considerable attention due to its emphasis on active learning,

collaboration, critical thinking, and authentic problem-solving experiences. Through PBL, students are encouraged to engage actively with real-world problems, construct knowledge collaboratively, and develop higher-order thinking skills required in increasingly complex learning environments (Barrows, 1986; Hmelo-Silver, 2004). Recent studies further indicate that PBL positively contributes to student engagement, collaborative learning, and critical thinking across various educational settings (Servant-Miklos & Kolmos, 2022; Dolmans et al., 2016).

At the same time, STEM education has become an important global educational agenda because of its potential to strengthen interdisciplinary learning, technological competencies, creativity, and problem-solving abilities required in modern societies (Bybee, 2013; Li et al., 2022). Integrated STEM approaches encourage learners to apply scientific reasoning and engineering design processes within authentic learning contexts (Kelley & Knowles, 2016). In parallel, AI technologies have further transformed educational practices through intelligent tutoring systems, adaptive learning environments, learning analytics, and AI-supported instructional tools (Zawacki-Richter et al., 2019; Bond et al., 2024). These technologies offer opportunities to enhance personalised learning, learner engagement, and instructional flexibility (Tlili et al., 2023).

Despite these promising developments, research related to the integration of PBL, STEM, and AI remains fragmented across different educational domains and thematic perspectives. Existing studies often focus on isolated pedagogical approaches or specific technological applications rather than comprehensively examining the convergence of PBL, STEM, and AI within a unified educational framework (Li et al., 2022; Bond et al., 2024). In addition, concerns remain regarding ethical implementation, teacher readiness, digital inequality, and overreliance on AI-supported educational systems (Selwyn, 2019; Williamson & Eynon, 2020). Therefore, further research is needed to explore sustainable pedagogical integration that effectively combines PBL, STEM, and AI to support meaningful learning experiences and twenty-first century competencies.

Furthermore, previous bibliometric studies generally focused on limited bibliometric indicators such as citation trends, thematic mapping, co-authorship networks, and keyword co-occurrence analysis. Consequently, the broader intellectual structure, publication dynamics, and global development of research related to PBL integrated with STEM and AI remain insufficiently explored. Therefore, the present study conducts a bibliometric analysis of global research on Problem-Based Learning integrated with STEM and Artificial Intelligence in education. Specifically, the study examines the current state of research, publication trends, influential contributors including authors, institutions, and countries, as well as the major thematic clusters and intellectual structures that characterise the development of this research field. Through this analysis, the study aims to provide a clearer understanding of the evolving research landscape and future direction of PBL integrated with STEM and AI in education. Unlike previous bibliometric studies that focused on isolated themes such as STEM education, project-based learning, or AI-supported learning separately, this study provides a more comprehensive intellectual mapping of the convergence between Problem-Based Learning, STEM, and Artificial Intelligence within educational research.

Research Motivation and Contribution

The motivation for this study stems from the rapid expansion of educational research related to Problem-Based Learning (PBL), STEM education, and Artificial Intelligence (AI), alongside the growing need to understand how these domains converge to support twenty-first-century learning. Although previous studies have examined these areas separately, limited attention has been given to systematically mapping their combined development within a unified educational framework. This lack of comprehensive understanding creates challenges for researchers, educators, and policymakers in identifying influential research trends, emerging themes, and future directions.

Therefore, this study contributes to the literature by providing a comprehensive bibliometric analysis of global research on PBL integrated with STEM and AI in education. Unlike previous bibliometric studies that focused on isolated themes, this study offers a holistic intellectual mapping of publication growth, influential authors, institutions, countries, citation impact, and thematic developments based on a large dataset of 477 publications. The findings provide valuable insights into the evolution of this emerging research field and establish a foundation for future empirical and theoretical investigations.

Literature Review

The integration of Problem-Based Learning (PBL), Science, Technology, Engineering, and Mathematics (STEM), and Artificial Intelligence (AI) has increasingly attracted scholarly attention in contemporary educational research. This growing interest reflects the increasing demand for learner-centred pedagogies capable of developing critical thinking, collaboration, creativity, and problem-solving skills required in twenty-first century education (Bybee, 2013; Li et al., 2022). PBL emphasises authentic problem-solving, collaborative inquiry, and active learning processes that encourage learners to construct knowledge through contextual learning experiences (Barrows, 1986; Hmelo-Silver, 2004). Previous studies indicate that PBL positively contributes to learner engagement, collaborative learning, and higher-order thinking skills across various educational contexts (Prince, 2004; Dolmans et al., 2016).

At the same time, STEM education has become an important global educational agenda because of its interdisciplinary orientation and its potential to prepare students for technologically driven societies (English, 2016; Kelley & Knowles, 2016). Recent literature further highlights that STEM-oriented pedagogies support creativity, inquiry skills, and problem-solving abilities, particularly when combined with active learning approaches such as PBL (Li et al., 2022; Goos et al., 2023).

Meanwhile, AI technologies have increasingly transformed educational practices through adaptive learning systems, learning analytics, intelligent tutoring systems, and AI-supported instructional tools (Zawacki-Richter et al., 2019; Bond et al., 2024). These technologies offer opportunities to enhance personalised learning, learner engagement, and instructional flexibility (Tlili et al., 2023). However, concerns remain regarding ethical implementation, teacher readiness, digital inequality, and overreliance on AI-supported educational systems (Selwyn, 2019; Williamson & Eynon, 2020).

Despite the increasing number of studies related to PBL, STEM, and AI, research integrating all three domains within a unified educational framework remains limited. Existing studies

frequently examine these areas separately, resulting in fragmented conceptual and thematic development. Consequently, the broader intellectual structure, publication dynamics, and thematic evolution of research related to PBL integrated with STEM and AI remain insufficiently explored. Therefore, this study addresses this gap by conducting a comprehensive bibliometric analysis of global research trends related to PBL-STEM-AI integration in education.

Overall, the existing literature indicates that research related to Problem-Based Learning (PBL), STEM education, Artificial Intelligence (AI), and problem-solving skills has expanded considerably in recent years and covers a wide range of educational themes. As shown in Table 1, previous studies have examined areas such as Creative Problem Solving (CPS) in education, Project-Based Learning integrated with STEM (PjBL-STEM), Problem-Based Learning in higher mathematics education, and STEM-based problem-solving skills. Commonly discussed topics include active learning approaches, critical thinking, collaboration, digital learning technologies, learning analytics, and the integration of AI within STEM-oriented educational practices. Nevertheless, the existing body of literature remains fragmented across different educational domains, methodologies, and thematic perspectives. Therefore, the present bibliometric study aims to provide a more comprehensive and structured overview of research on Problem-Based Learning integrated with STEM and Artificial Intelligence (AI) in education by systematically mapping publication patterns, research trends, influential contributors, and thematic developments related to RQ1–RQ4. Such analysis is expected to provide researchers, educators, and policymakers with clearer insights into the development and future direction of this research field.

Despite the important contributions made by previous studies, several research gaps remain and justify the need for further investigation:

- i. **Scope of Integration:** Existing bibliometric studies have primarily focused on isolated themes such as Creative Problem Solving (Yuniasih et al., 2025), PjBL-STEM integration (Usman et al., 2026), mathematics-focused PBL (Meiliati et al., 2026), and STEM problem-solving skills (Manasikana et al., 2025). However, limited studies have comprehensively examined the integration of Problem-Based Learning, STEM, and Artificial Intelligence simultaneously within educational contexts.
- ii. **Technological Emphasis:** Although several studies discussed digital learning, learning analytics, and educational technologies, the explicit role of Artificial Intelligence (AI) in supporting PBL-STEM implementation remains underexplored. Previous studies mainly focused on learning outcomes, thematic mapping, or problem-solving skills without thoroughly analysing AI-driven educational practices and emerging intelligent learning environments.
- iii. **Bibliometric Coverage and Dataset Size:** Prior studies generally analysed relatively small and specialised datasets ranging from 68 to 250 publications. Most studies concentrated on limited bibliometric indicators such as keyword co-occurrence, thematic mapping, citation trends, or collaboration networks. In contrast, the present study analyses a broader dataset consisting of 477 publications covering the period from 1997 to 2026, allowing a more comprehensive and updated understanding of publication trends, citation performance, influential contributors, institutional productivity, country distribution, and thematic evolution.

- iv. **Research Landscape Consolidation:** Existing studies remain dispersed across multiple educational subfields, including STEM education, higher education mathematics, creative problem-solving, and project-based learning. Consequently, there is still a lack of a unified bibliometric mapping that specifically consolidates research related to Problem-Based Learning integrated with STEM and AI in education. This study addresses this gap by providing a holistic bibliometric profile that integrates publication trends, citation analysis, co-occurrence networks, thematic structures, and global research distributions within a single analytical framework.

Overall, the broader scope, extended temporal coverage, and comprehensive bibliometric indicators employed in this study enable a more systematic exploration of emerging themes, scholarly influence, and conceptual developments that previous studies with narrower scopes and smaller datasets were unable to fully capture.

Table 1

Previous Bibliometric Studies on Problem-Based Learning, STEM, and Artificial Intelligence (AI) in Education

Authors	Objective	Data & Year Cover	Source	Total Document	Bibliometric Attributes Examined
Yuniasih et al. (2025)	To examine trends, key themes, and gaps in Creative Problem Solving (CPS) research in education.	Scopus (2007–2024)	Scopus	68 publications	Publication trends, citation trends, VOSviewer visualisation, thematic development, methodological approaches, highest-cited publications.
Usman et al. (2026)	To map the integration of Project-Based Learning in STEM education and identify research gaps, especially involving AI and learning analytics.	Scopus (2014–2025)	Scopus	102 documents	Publication trends, citation indicators, keyword co-occurrence, co-word network, thematic clusters, centrality metrics, thematic map, AI and learning analytics position.
Meiliati et al. (2026)	To map global trends, influential authors, institutional networks, and thematic structures of PBL in higher mathematics education.	Scopus (accessed 24 February 2025)	Scopus	250 publications	Publication dynamics, collaboration patterns, keyword co-occurrence, influential authors, countries, citation analysis, thematic clusters using Biblioshiny R and VOSviewer.

Manasikana et al. (2025)	To explore research trends on problem-solving skills in STEM education, focusing on teaching methods for science education majors.	Scopus (2010–2025)	Scopus	192 publications*	Publication trends, co-authorship networks, co-citation, keyword co-occurrence, citation metrics, h-index, citation counts, geographical distribution, influential studies.
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Research Questions

This paper presents a bibliometric analysis of research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education by focusing on four main research questions (RQs):

RQ1: What is the current state of research on Problem-Based Learning integrated with STEM and AI in education?

RQ2: What emerging trends are observable in scholarly publications related to the integration of Problem-Based Learning, STEM, and AI in education?

RQ3: Who are the leading contributors — authors, institutions, and countries — in advancing research on Problem-Based Learning integrated with STEM and AI?

RQ4: What are the core research themes, conceptual clusters, and intellectual structures that define the development and evolution of Problem-Based Learning integrated with STEM and AI in education?

Methods

The dataset examined in this study was obtained from the Scopus database on 13 May 2026. Scopus was selected as the primary source of data due to its reputation as one of the most comprehensive and reliable databases for peer-reviewed scholarly publications, providing extensive coverage of abstracts and citation information. Its multidisciplinary nature, especially in the fields of science, technology, medicine, and social sciences, makes it highly appropriate for exploring research related to Problem-Based Learning (PBL), STEM, and Artificial Intelligence (AI) in education. Furthermore, Scopus is recognised for maintaining strict indexing standards and offering broad international coverage, which enhances the credibility and robustness of bibliometric analyses. The database also supplies comprehensive metadata, such as citation details and author affiliations, supporting its suitability as the main data source for this study (Aghaei Chadegani et al., 2013). The retrieved records included information related to document type, source type, language, subject area, publication patterns, average authors per document, institutional productivity, country contributions, and frequently occurring keywords.

Search Strategy

This study was guided by the PRISMA 2020 statement developed by Page et al. (2021) to ensure a systematic, transparent, and rigorous screening process. The Scopus database was selected as the primary source of data because of its extensive coverage of peer-reviewed scholarly publications and its suitability for bibliometric research in the fields of education, STEM, and Artificial Intelligence (AI). A structured search query using Boolean operators was

developed to identify studies related to Problem-Based Learning (PBL) integrated with STEM and AI in educational settings. The search string applied was:

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TITLE-ABS-KEY ( ( "problem-based learning" OR "PBL" OR "experiential learning" OR "active learning" ) AND ( "STEM" OR "science" OR "technology" OR "engineering" OR "mathematics" ) AND ( "artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" ) AND ( "education" OR "teaching" OR "curriculum" OR "instruction" ) AND ( "student engagement" OR "critical thinking" OR "collaboration" OR "problem solving" ) ) AND ( LIMIT-TO ( SUBJAREA , "SOCI" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) OR LIMIT-TO ( DOCTYPE , "cp" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO ( PUBSTAGE , "final" ) )
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The search strategy was designed to capture a broad range of studies focusing on Problem-Based Learning integrated with STEM and AI within educational contexts. Filters were applied in Scopus to limit the search to the Social Sciences subject area, English-language publications, and documents in the final publication stage. Both journal articles and conference proceedings were included to ensure comprehensive coverage of scholarly contributions in this research area.

As illustrated in the PRISMA flow diagram, the initial search identified 1,045 records from the Scopus database. During the identification stage, 468 records were automatically removed because they did not belong to the Social Sciences subject area. This process resulted in 577 records being retained for screening. Subsequently, automation tools excluded 79 records consisting of document types other than articles and conference proceedings, leaving 498 reports for retrieval.

At the retrieval stage, one report could not be obtained because its metadata could not be retrieved from the database. Consequently, 497 reports were assessed for eligibility. During the eligibility assessment, 20 studies were excluded because they were not in the final publication stage, while no studies were excluded due to language limitations since all remaining documents were published in English.

Following the systematic screening and eligibility process, a total of 477 studies were included in the final review and bibliometric analysis. This rigorous screening procedure ensured that the dataset consisted only of relevant, high-quality, and accessible studies aligned with the objectives of the present research.

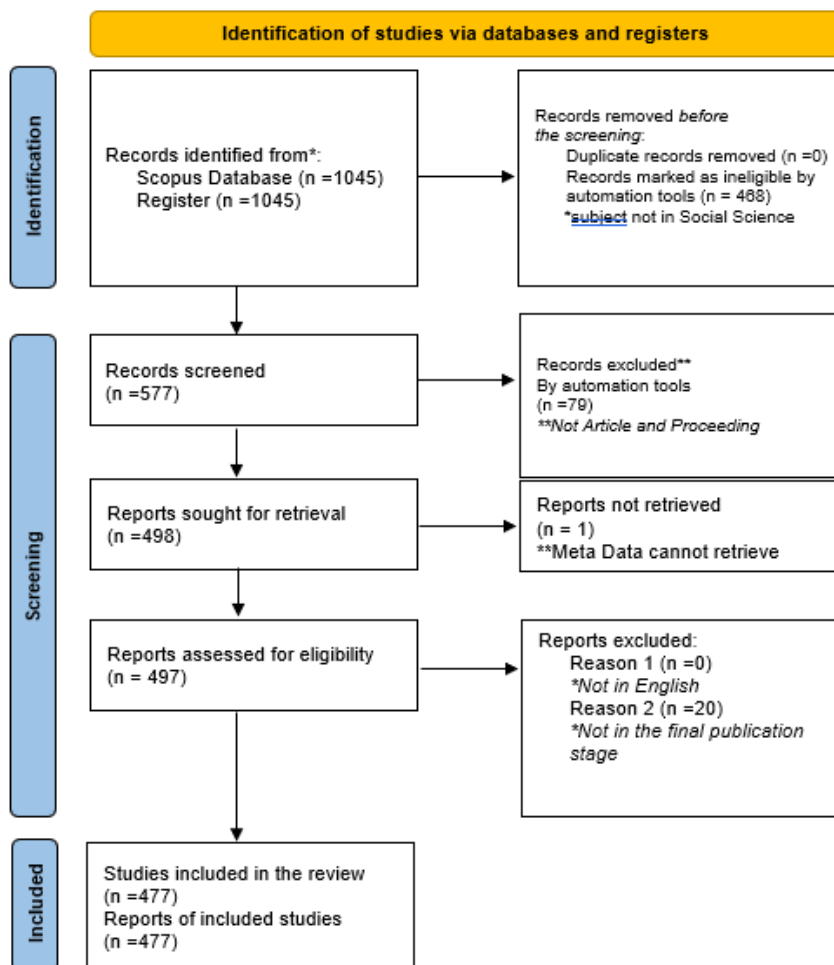


Fig. 1. Flow Diagram of the Search Strategy (Page et al., 2021).

Data Cleaning and Harmonisation

To ensure the accuracy and consistency of the bibliometric analysis, the dataset underwent a systematic cleaning and harmonisation process using OpenRefine and biblioMagika® (Ahmi, 2023). Key bibliographic elements such as author names, affiliations, keywords, and metadata were standardised to minimise inconsistencies in indexing and naming conventions that could affect bibliometric results. The Scopus dataset was first exported in CSV format and processed using OpenRefine's clustering and refinement functions to identify and correct inconsistencies, duplicate records, and formatting variations. After the standardisation process, biblioMagika® was used to generate bibliometric indicators related to publication year, authors, institutions, countries, and source titles. The indicators analysed included Total Publications (TP), Number of Contributing Authors (NCA), Number of Cited Publications (NCP), Total Citations (TC), Citations per Publication (C/P), Citations per Cited Publication (C/CP), h-index, g-index, m-index, and Citation Sum within the h-Core. The software also assisted in detecting missing or incomplete data, allowing further manual verification to improve the overall reliability and quality of the final dataset.

Data Analysis

To address the research questions, this study employed a bibliometric analytical approach to examine the development of research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. The analysis began by describing the overall characteristics of the dataset, including document type, publication source, language, subject area, and citation information. Subsequently, several bibliometric dimensions were analysed, such as annual publication trends, productive authors, leading institutions, contributing countries, and influential journals or source titles, to identify major research patterns and key contributors within the field. Research impact was evaluated using bibliometric indicators including Total Publications (TP), Number of Cited Publications (NCP), Total Citations (TC), Citations per Publication (C/P), Citations per Cited Publication (C/CP), h-index, g-index, m-index, and Citation Sum within the h-core. In addition, the conceptual structure of the research area was explored through co-occurrence network analysis, thematic mapping, and factorial analysis based on authors' keywords. These analytical techniques assisted in identifying major research themes, emerging topics, and the interrelationships among different research areas within the field.

Tools

Several specialised tools were employed to enhance the accuracy and reliability of the bibliometric analysis. Microsoft Excel was used for the initial organisation and management of the Scopus dataset. Subsequently, biblioMagika® was utilised to standardise metadata and resolve inconsistencies related to author names, institutional affiliations, and country information. OpenRefine further supported the harmonisation of authors' keywords to improve consistency during the co-occurrence analysis. For the visualisation stage, VOSviewer was applied to generate bibliometric network maps, including keyword co-occurrence patterns, author collaboration networks, and citation relationships. These tools collectively supported a more systematic and reliable bibliometric analysis.

Results

The following section presents the findings of the bibliometric analysis conducted on research related to Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education, based on the research questions of this study. By analysing major publication patterns, research trends, authorship contributions, institutional involvement, country distribution, and thematic developments, the study provides a comprehensive overview of the evolution and current state of this research area. The findings offer valuable insights for researchers, educators, curriculum developers, and policymakers in understanding the growing integration of PBL, STEM, and AI within educational contexts.

Current State of Research

To address RQ1, which focuses on identifying the current state of research in this field, bibliometric indicators generated using biblioMagika® for the period 1997 to 2026 were analysed. These indicators provide a comprehensive overview of publication productivity, authorship patterns, and citation performance, thereby reflecting the overall development and scholarly influence of the research area.

As presented in Table 2, the dataset comprises 477 publications produced over 30 citable years, indicating that research in this field has developed progressively over a long period.

The publications involved 1,630 contributing authors, demonstrating substantial scholarly participation and continuous academic interest in the area. Among the total publications, 310 papers have received citations, suggesting that a significant proportion of the studies has gained recognition within the academic community.

In terms of citation performance, the dataset accumulated a total of 4,747 citations. The average citation per paper is 9.95, while the average citation per cited paper is considerably higher at 15.31. This indicates that publications receiving scholarly attention tend to achieve relatively strong citation impact. Furthermore, the annual citation rate reached 163.69 citations per year, reflecting a steady pattern of research influence across time.

From the authorship perspective, the average citation per author is 2.91, suggesting moderate recognition of individual scholarly contributions. The author-per-paper ratio of 3.42 also indicates collaborative research practices within the field. Additionally, the citation sum within the h-core recorded 4,147 citations, highlighting the cumulative impact of the most influential publications in the dataset.

The bibliometric performance is further reflected through an h-index of 34, g-index of 57, and m-index of 1.133. These findings indicate the presence of a stable and influential body of literature, with several highly cited core publications contributing significantly to the advancement of the field.

Table 2

Citation Metric

Main Information	Data
Publication Years	1997 - 2026
Total Publications	477
Citable Year	30
Number of Contributing Authors	1630
Number of Cited Papers	310
Total Citations	4,747
Citation per Paper	9.95
Citation per Cited Paper	15.31
Citation per Year	163.69
Citation per Author	2.91
Author per Paper	3.42
Citation sum within h-Core	4,147
h-index	34
g-index	57
m-index	1.133

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2023)

Publication Trends

To address RQ2, which focuses on publication trends in this field, the yearly distribution of publications and citations from 1997 to 2026 was analysed, as illustrated in Fig. 2. The findings demonstrate considerable fluctuations in both publication productivity and citation performance over time, reflecting the evolving development and scholarly attention given to

research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education.

As presented in Table 3, research activity during the early years was relatively limited, with only one publication recorded in 1997 and two publications in 2001 and 2003. Despite the small number of studies, some publications achieved notable citation impact. For example, publications in 2001 accumulated 103 citations with an average citation per publication (C/P) of 51.50, indicating the strong influence of several pioneering studies in the field.

A gradual increase in publication productivity became more apparent beginning in 2014, where the number of publications rose to 10 and continued to increase steadily in subsequent years. Between 2015 and 2019, the field experienced substantial growth, with publications increasing from 28 to 21 studies annually while citation counts also remained relatively high. Notably, 2019 recorded the highest citation count of 672 citations, demonstrating the significant scholarly influence of studies published during this period.

The upward trend in research productivity continued after 2020. As shown in Fig. 2 and Table 3, publication output increased from 20 publications in 2021 to 74 publications in 2024. The highest number of publications was recorded in 2025 with 149 publications, indicating rapid expansion and growing academic interest in integrating PBL, STEM, and AI within educational research. However, citation counts showed a declining pattern in the most recent years, particularly in 2025 and 2026. This decline is likely due to citation lag, as newer publications generally require more time to accumulate citations within the academic community.

Overall, the publication trend demonstrates that this field has evolved from a relatively small research area into a rapidly growing domain with increasing scholarly participation and research impact. The consistent rise in publication output suggests expanding interest, broader research collaboration, and the continuing relevance of PBL integrated with STEM and AI in education.

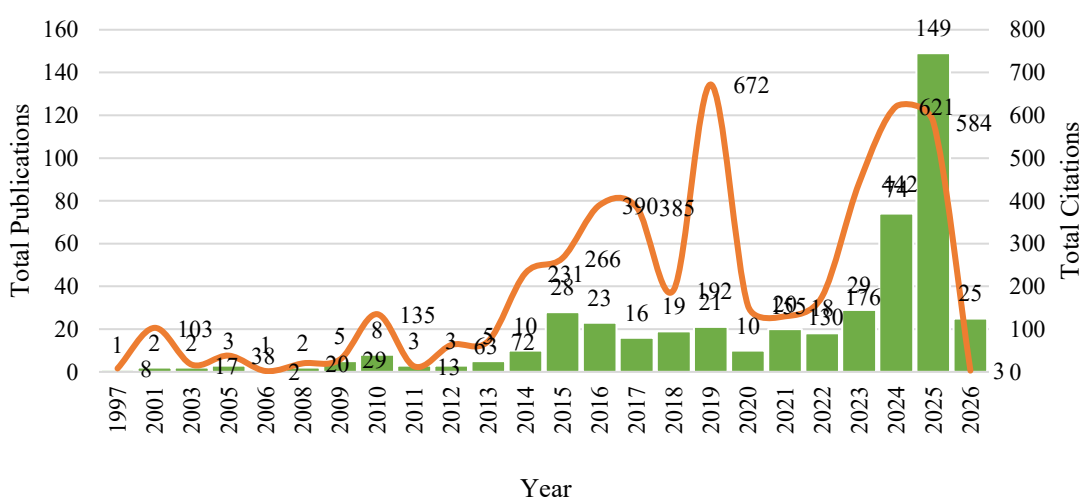


Fig. 2. Total Publications and Citations by Year (data is only available up to 13 May 2026).

Table 3

Publication by Year

Year	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
1997	1	3	1	8	8.00	8.00	1	1	0.033
2001	2	4	2	103	51.50	51.50	2	2	0.077
2003	2	6	2	17	8.50	8.50	2	2	0.083
2005	3	6	3	38	12.67	12.67	1	3	0.045
2006	1	1	1	2	2.00	2.00	1	1	0.048
2008	2	4	2	20	10.00	10.00	2	2	0.105
2009	5	18	4	29	5.80	7.25	3	5	0.167
2010	8	19	5	135	16.88	27.00	4	8	0.235
2011	3	5	3	13	4.33	4.33	2	3	0.125
2012	3	7	3	63	21.00	21.00	2	3	0.133
2013	5	9	5	72	14.40	14.40	3	5	0.214
2014	10	33	8	231	23.10	28.88	5	10	0.385
2015	28	80	24	266	9.50	11.08	7	15	0.583
2016	23	67	21	390	16.96	18.57	8	19	0.727
2017	16	39	14	385	24.06	27.50	9	16	0.900
2018	19	54	17	192	10.11	11.29	7	13	0.778
2019	21	76	19	672	32.00	35.37	13	21	1.625
2020	10	39	10	155	15.50	15.50	8	10	1.143
2021	20	54	17	130	6.50	7.65	6	10	1.000
2022	18	72	14	176	9.78	12.57	7	13	1.400
2023	29	131	24	442	15.24	18.42	8	20	2.000
2024	74	289	49	621	8.39	12.67	13	23	4.333
2025	149	541	59	584	3.92	9.90	11	22	5.500
2026	25	73	3	3	0.12	1.00	1	1	1.000
Total	477	1630	310	4747	9.95	15.31	34	57	1.133

Notes: TP = Total number of Publications; NCA = Number of Contributing Authors; NCP = Number of Cited Publications; TC = Total Citations; C/P = average Citations per Publication; C/CP = average Citations per Cited Publication; h = h-index; g = g-index; m = m-index.

* *Publication data for 2026 is only up to 13 May 2026*

Publications by authors

To address RQ3, Table 4 presents the top five most productive authors who contributed significantly to research related to Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. The table summarises several bibliometric indicators, including total publications (TP), total citations (TC), citation averages (C/P and C/CP), as well as author impact indices such as the h-index, g-index, and m-index, to identify influential contributors within the field.

As shown in Table 4, all five authors produced three publications each, indicating a relatively balanced level of productivity among the leading contributors. However, differences can be observed in terms of citation performance and scholarly impact. Borrego, Maura from the University of Texas and Shekhar, Prateek from the University of Michigan recorded the highest total citations, with 55 citations each. Both authors also achieved the highest average citations per publication (C/P = 18.33) and citations per cited publication (C/CP = 18.33),

demonstrating strong academic influence and visibility within the research domain.

Meanwhile, Membrillo-Hernández, Jorge from the Institute for the Future of Education in Mexico accumulated 44 total citations with a citation average of 14.67 per publication, reflecting meaningful scholarly impact. Ramasamy, Vijayalakshmi from Georgia Southern University recorded 15 citations with a moderate citation performance ($C/P = 5.00$).

Although Omeh, Christian Basil from the University of Nigeria obtained the lowest citation count ($TC = 6$), the author achieved the highest m-index value ($m = 1.000$), indicating a relatively consistent citation growth rate over time. Overall, the findings in Table 4 suggest that research contributions in this field are internationally distributed and supported by scholars from diverse institutional and geographical backgrounds.

Table 4

Top 5 Most Productive Authors

Full Name	Current Affiliation	Country	T P	N CP	T C	C/P	C/C P	h	g	m
Membrillo-Hernández, Jorge	Institute for the Future of Education	Mexico	3	3	4	14.67	14.67	2	3	0.250
Borrego, Maura	University of Texas	United States	3	3	5	18.33	18.33	3	3	0.300
Ramasamy, Vijayalakshmi	Georgia Southern University	United States	3	3	15	5.00	5.00	2	3	0.400
Omeh, Christian Basil	University of Nigeria	Nigeria	3	3	6	2.00	2.00	2	2	1.000
Shekhar, Prateek	University of Michigan	United States	3	3	5	18.33	18.33	3	3	0.300

Notes: TP = Total number of Publications; NCP = Number of Cited Publications; TC = Total Citations; C/P = average Citations per Publication; C/CP = average Citations per Cited Publication; h = h-index; g = g-index; m = index.

Publications by Institutions

Table 5 presents the most productive institutions contributing to research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. The table highlights institutional productivity and research impact through several bibliometric indicators, including total publications (TP), total citations (TC), citation averages (C/P and C/CP), and institutional h-, g-, and m-indices. These indicators provide insights into the leading institutions driving scholarly development within the field.

As shown in Table 5, Tecnológico de Monterrey from Mexico emerges as the most productive institution, contributing 17 publications with a total of 111 citations. The institution also recorded a citation average of 6.53 citations per publication (C/P) and 9.25 citations per cited publication (C/CP). Its h-index of 5 and g-index of 10 indicate a stable and influential research contribution within the field.

Among institutions from the United States, the University of Michigan and the University of Wisconsin demonstrated notable productivity, contributing nine and eight publications respectively. The University of Wisconsin accumulated 76 citations, slightly higher than the

University of Michigan with 63 citations, reflecting stronger citation performance despite lower publication output. Meanwhile, the Massachusetts Institute of Technology (MIT) recorded only six publications but achieved 102 total citations, resulting in a relatively high citation average ($C/P = 17.00$; $C/CP = 25.50$), suggesting strong scholarly influence.

Arizona State University also demonstrated significant citation impact, accumulating 91 citations from four publications and achieving the highest citation average in the table ($C/P = 22.75$; $C/CP = 30.33$). Overall, the findings in Table 5 indicate that research contributions in this field are internationally distributed, with institutions from the United States, Mexico, Europe, and Latin America actively advancing scholarship related to PBL, STEM, and AI integration in education.

Table 5

Most Productive Institutions

Institution Name	Country	T P	NC A	NC P	TC	C/P	C/C P	h	g	m
Tecnologico de Monterrey	Mexico	1	72	12	11	6.5	9.2	5	1	0.6
		7			1	3	5			0
University of Michigan	United States	9	25	8	63	7.0	7.8	4	7	0.3
						0	8			
University of Wisconsin	United States	8	21	7	76	9.5	10.	5	8	0.5
						0	86			
Massachusetts Institute of Technology	United States	6	18	4	10	17.	25.	4	6	0.3
					2	00	50			
Queen Mary University of London	United Kingdom	6	15	4	62	10.	15.	2	6	0.2
						33	50			
Aalborg University	Denmark	4	7	3	36	9.0	12.	3	4	0.1
						0	00			
University of North Carolina at Chapel Hill	United States	4	16	3	20	5.0	6.6	3	4	0.2
						0	7			
Universidad de los Andes	Chile	4	14	2	7	1.7	3.5	2	2	0.4
						5	0			
Arizona State University	United States	4	5	3	91	22.	30.	3	4	0.2
						75	33			
University of Pittsburgh	United States	4	7	4	13	3.2	3.2	2	3	0.1
						5	5			

Notes: TP = Total number of Publications; NCP = Number of Cited Publications; TC = Total Citations; C/P = average Citations per Publication; C/CP = average Citations per Cited Publication; h = h-index; g = g-index; m = index.

Publications by Countries

Table 6 presents a comparative overview of countries contributing to research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. The global distribution of publications, as illustrated in Fig. 3, demonstrates broad international participation, with several countries showing substantial productivity and scholarly influence. The table summarises important bibliometric indicators, including total publications (TP), total citations (TC), citation averages (C/P and C/CP), as well as country-level h-, g-, and m-indices.

As shown in Table 6 and Fig. 3, the United States emerges as the leading contributor, recording 137 publications and accumulating 1,442 total citations. The country also achieved an h-index of 19 and a g-index of 37, indicating a strong and influential research presence. With citation averages of $C/P = 10.53$ and $C/CP = 14.00$, the United States demonstrates stable scholarly impact and consistent research productivity within the field.

China ranks as the second most productive country with 37 publications and 533 citations. Notably, China recorded the highest citation average per cited publication ($C/CP = 44.42$) among the listed countries, suggesting that its cited studies have achieved substantial academic visibility. The country also obtained an h-index of 6 and a g-index of 23, reflecting growing research influence.

The United Kingdom follows closely with 35 publications and 367 citations. Its citation averages ($C/P = 10.49$; $C/CP = 14.68$) indicate a relatively strong citation performance. Meanwhile, Australia and India each contributed 24 publications, although Australia demonstrated considerably higher citation impact with 525 citations compared to India's 91 citations.

Other active contributors include Spain, Mexico, Brazil, Canada, and Portugal. Among these countries, Canada displayed notable citation strength with 269 total citations and a relatively high C/P value of 15.82. Overall, the findings presented in Fig. 3 and Table 6 indicate that research on PBL integrated with STEM and AI is globally distributed and continues to attract increasing scholarly attention across multiple regions worldwide.

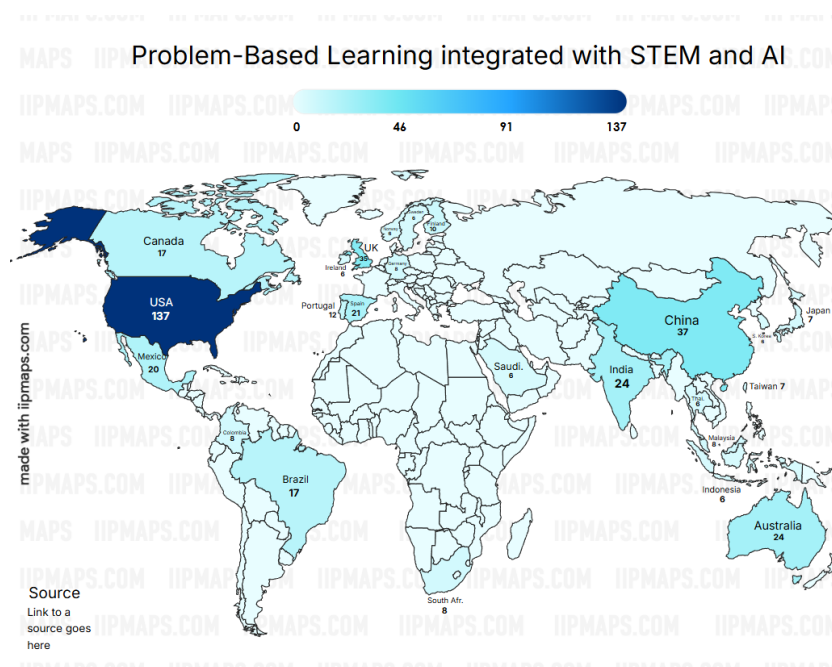


Fig. 3. Visualisation of Global Distribution Problem-Based Learning integrated with STEM and AI Publications

As shown in Figure 4, “active learning” appears as the most dominant and highly connected keyword, indicating its central role in studies related to PBL, STEM, and AI integration. Closely linked to this keyword are “engineering education,” “project-based learning,” “higher education,” “artificial intelligence,” and “critical thinking,” reflecting the strong emphasis on student-centred learning approaches and technology-enhanced education.

The network also reveals several thematic clusters. The red cluster focuses on themes such as “collaboration,” “teamwork,” “gamification,” “assessment,” and “computational thinking.” This cluster highlights research related to interactive learning strategies, learner engagement, and the development of higher-order thinking skills within STEM-oriented educational environments.

The green cluster is centred around “artificial intelligence,” “computer science education,” “online learning,” “teaching,” and “learning environment.” These keywords indicate growing scholarly interest in integrating AI technologies into digital learning environments and instructional practices. Terms such as “ethics” and “lifelong learning” further suggest increasing concern regarding responsible AI implementation and sustainable educational development.

Meanwhile, the blue cluster includes keywords such as “educational technology,” “simulation,” “virtual reality,” and “deep learning,” representing the technological dimension of the research field. This cluster reflects studies examining emerging technologies that support experiential and immersive learning approaches.

The yellow and orange clusters are associated with “engineering education,” “team-based learning,” “software engineering,” “soft skills,” and “sustainability.” These themes demonstrate the interdisciplinary nature of the field and emphasise the importance of collaborative problem-solving, technical competencies, and real-world applications in STEM education.

Overall, Figure 4 demonstrates that research on PBL integrated with STEM and AI is highly interconnected, multidisciplinary, and increasingly focused on active learning, technological innovation, and student-centred educational practices.

Discussion

The findings of this bibliometric analysis demonstrate that research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education has expanded substantially over the past three decades. The increasing publication output, citation visibility, and thematic diversity suggest that the field has evolved from a relatively fragmented area into a more structured and multidisciplinary research domain. This development reflects the growing emphasis on student-centred pedagogies and technology-enhanced learning approaches capable of supporting twenty-first century competencies such as critical thinking, collaboration, creativity, and problem-solving skills. Previous studies similarly highlighted that active learning approaches, particularly PBL, contribute significantly to meaningful learning experiences and higher-order thinking development (Prince, 2004; Hmelo-Silver, 2004).

The publication trend identified in this study reveals strong research acceleration after 2014 and rapid growth between 2023 and 2025. This pattern indicates that the integration of PBL, STEM, and AI is increasingly recognised as an important educational research stream rather than merely an emerging innovation. The expansion may be associated with rapid advancements in AI technologies, growing international attention towards STEM education, and increasing demand for pedagogical approaches that prepare learners to solve complex real-world problems. Similar growth patterns were reported in previous bibliometric studies on STEM education and problem-solving research (Yuniasih et al., 2025; Manasikana et al., 2025). However, despite the growing number of publications, the field still appears methodologically fragmented. Many studies continue to focus on technology adoption and perception-based analyses, while empirical evidence examining long-term pedagogical effectiveness remains comparatively limited.

The findings further reveal that research productivity remains geographically concentrated within several technologically advanced countries. The United States, China, and the United Kingdom emerged as dominant contributors, while institutions such as Tecnológico de Monterrey, the University of Michigan, and the Massachusetts Institute of Technology demonstrated strong institutional visibility. This uneven distribution may reflect disparities in research funding, technological infrastructure, institutional capacity, and international database visibility. Similar observations were reported by Zawacki-Richter et al. (2019), who argued that educational technology research is frequently dominated by countries with stronger technological ecosystems. Although this concentration may accelerate innovation, it also limits the representation of diverse educational and cultural contexts. Therefore, broader international collaboration involving underrepresented regions is necessary to ensure more inclusive research development.

The co-occurrence analysis further demonstrates that the field is organised around several interconnected thematic clusters. Keywords such as “active learning,” “engineering education,” “project-based learning,” “artificial intelligence,” and “critical thinking” emerged as central themes within the research network. This finding indicates that current scholarship strongly emphasises learner-centred pedagogies and technology-supported educational practices. Themes related to collaboration, teamwork, computational thinking, and gamification further suggest increasing scholarly concern with enhancing learner engagement and higher-order thinking skills. These findings align with constructivist and inquiry-based learning perspectives, which emphasise active knowledge construction and authentic problem-solving experiences (Barrows, 1986; Hmelo-Silver, 2004).

The thematic clusters also reveal increasing interest in AI-driven learning environments and emerging educational technologies. Keywords such as “online learning,” “simulation,” “virtual reality,” and “educational technology” indicate that the field is becoming increasingly interdisciplinary and technologically sophisticated. At the same time, themes related to “ethics,” “lifelong learning,” and “soft skills” reflect growing awareness regarding the broader implications of AI integration in education. This suggests that future studies should move beyond technological implementation and examine issues related to ethical AI use, learner diversity, teacher readiness, and digital equity more critically.

Despite the growing visibility of AI-related themes, the findings suggest that AI integration within PBL-STEM environments remains pedagogically underdeveloped, as many studies continue to emphasise technological applications rather than instructional design and learner-centred implementation.

Overall, the findings suggest that research on PBL integrated with STEM and AI is continuing to evolve as an influential educational research field. Nevertheless, more longitudinal, mixed-method, and experimental studies are still needed to examine the actual effectiveness of AI-supported PBL and STEM practices on student achievement, critical thinking, communication skills, and problem-solving performance across different educational contexts. The findings of this study may provide useful implications for educators, curriculum developers, and policymakers in designing more integrated, technology-enhanced, and problem-oriented learning environments.

Conclusion

This bibliometric analysis provides a comprehensive overview of global research on Problem-Based Learning (PBL) integrated with STEM and Artificial Intelligence (AI) in education. By examining publication trends, citation patterns, and keyword co-occurrence networks, the study highlights the growing importance of learner-centred pedagogies and technology-enhanced educational practices in contemporary education. The findings demonstrate that research in this field has expanded substantially, particularly in recent years, reflecting increasing scholarly interest in integrating AI-supported learning environments with STEM-oriented and problem-based instructional approaches. The thematic analysis further reveals that concepts such as active learning, critical thinking, collaboration, engineering education, and educational technology have become central components within the evolving research landscape. The study also shows that the integration of PBL, STEM, and AI has strong potential to support authentic learning experiences, higher-order thinking skills, problem-solving abilities, and collaborative learning practices. Highly influential studies emphasise the role of AI-supported educational technologies in enhancing learner engagement, improving instructional flexibility, and supporting interdisciplinary learning environments. At the same time, the findings indicate growing scholarly concern regarding ethical AI implementation, digital equity, teacher readiness, and sustainable educational development. Overall, this study provides a nuanced understanding of the intellectual structure and developmental trajectory of research related to PBL integrated with STEM and AI in education. The findings highlight the importance of adopting balanced and pedagogically grounded approaches when integrating AI into educational contexts. As AI technologies continue to evolve, educators, researchers, and policymakers must work collaboratively to ensure responsible implementation, equitable access, and effective integration of AI-supported pedagogies that can meaningfully enhance teaching, learning, and future educational innovation.

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