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Inquiry-Integrated STEM in Physics Education: Bibliometric Trends and Potential Electromagnetic Induction Topic Gap (2020–2025)

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Abstract

Inquiry-based STEM integration matters more and more for building 21st-century skills in physics classrooms, yet few studies map the structure of this field, and fewer still address electromagnetic induction, a concept students find notoriously hard. This study maps trends, productivity, thematic structure, and possible topic gaps in inquiry-integrated STEM for physics education from 2020 to 2025. The analysis covered 59 Scopus-indexed documents selected through PRISMA screening and used Bibliometrix (RStudio/Biblioshiny) and VOSviewer version 1.6.21. Annual output fluctuated but rose overall and peaked at 17 documents in 2025. The Journal of Physics: Conference Series, AIP Conference Proceedings, and Physics Education published the most documents. Thematic mapping produced ten keyword clusters. Students and engineering education formed the strongest motor themes, while active learning and innovative projects stayed marginal, and VOSviewer showed the same pattern. No title, abstract, or keyword among the 59 documents contained electromagnetic induction or a closely related term. Three targeted Scopus verification searches returned seven further documents on electromagnetic induction with STEM or inquiry-based approaches, and none of them belonged to the dataset. The topic therefore appears under-represented in the analyzed dataset, while the wider literature does contain studies on it, and this conclusion applies only to Scopus and the search terms used. Future research could test inquiry-based STEM interventions on electromagnetic induction, which would also serve Sustainable Development Goal 4.

Keywords: bibliometric analysis; inquiry-based learning; STEM education; physics education; electromagnetic induction

Introduction

Learners in the twenty-first century need to think critically, create, collaborate, and communicate. Global problems rarely have simple answers, so these skills carry real weight. STEM education has gained prominence as an approach that combines science, technology, engineering, and mathematics in one framework and helps students link classroom concepts to practice outside school. Studies report that STEM integration deepens conceptual understanding and makes learning feel more relevant (Morais et al., 2025; Portillo-Blanco et al., 2025).

Inquiry-based learning stands out among STEM approaches. Students ask questions, run investigations, analyze evidence, and share what they find (Bembich & Bologna, 2025; Ganajová et al., 2025). Combined with STEM, inquiry reproduces how scientists and engineers actually work, and students develop higher-order thinking while they tackle real-world problems (Alanazi et al., 2024; Kapon et al., 2021). Science education researchers around the world now treat this combination as a major theme (Ladachart & Ladachart, 2026).

Physics education gains a great deal from this approach (Peer & Kapon, 2025). Physics often seems abstract and heavily mathematical to students, which makes it hard for them to connect it to daily life (Alabidi et al., 2023; Aprilia et al., 2023). Inquiry-based STEM narrows that distance. Hands-on experiments, engineering tasks, and technology make physics easier to approach (Zviel-Girshin & Rosenberg, 2025). A growing literature reports better conceptual understanding, scientific literacy, critical thinking, and motivation (Aktaş & Karamustafaoğlu, 2024; Al-Duhani et al., 2024; Conradty et al., 2020; Flegr et al., 2023). Atqiya et al. (2021) showed that argument-driven inquiry combined with STEM sharpened students' reasoning and argumentation. Comparable gains in scientific literacy, problem-solving, and self-concept appear in other studies (Abu Khurma & El Zein, 2024; Anwo et al., 2025; Dah et al., 2024; Premthaisong & Srisawasdi, 2024; Yuliati et al., 2021).

A comprehensive bibliometric map of inquiry-integrated STEM in physics education is still missing. Earlier bibliometric studies concentrate on general STEM trends in secondary physics or on project-based STEM. They tend to treat inquiry as background instead of the pedagogical core, and they say little about how topics are organized within the field (Agusti et al., 2026; Qamila et al., 2026; Syaifuddin et al., 2025). Topic coverage raises a second question, particularly for electromagnetic induction. The concept links magnetism and electricity, and students find it hard because they must coordinate magnetic fields, flux, and Lenz's law at the same time (Guisasola et al., 2013; Xie et al., 2025). Many also have trouble relating the law to everyday devices such as induction stoves or transformers (Jelicic et al., 2017). Inquiry-based interventions exist for many physics topics, but it is unclear how much of the Scopus-indexed inquiry-based STEM literature deals with electromagnetic induction. This study examines this question within the retrieved dataset and recognizes that other terminology or additional databases could reveal more studies.

This study responds to both gaps. This study conducted a bibliometric analysis of inquiry-integrated STEM in physics education for 2020–2025. It mapped publication trends, identified productive sources and countries, analyzed citation patterns, and examined the intellectual structure of the field. It also assessed how visible electromagnetic induction is in this literature, using keyword co-occurrence, thematic mapping, and targeted Scopus verification searches. Four research questions guide the work. First, how has annual publication output changed over time? Second, which sources, countries, and documents lead in productivity and influence? Third, what intellectual structure emerges from thematic mapping and keyword co-occurrence? Fourth, how visible is electromagnetic induction in this body of research? Answers to these questions should give a broad picture of the Scopus-indexed research landscape and can inform future learning interventions.

Method

This study used a descriptive quantitative bibliometric analysis. Bibliometric analysis examines patterns in bibliographic data, such as publication counts, citation links, and keyword co-occurrence, to reveal trends and structural gaps (Donthu et al., 2021; Zupic & Cater, 2015). PRISMA guidelines were applied to document selection only and were not used for qualitative

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synthesis. The approach made it possible to map a fast-growing but fragmented literature and to judge how visible specific topics, such as electromagnetic induction, are within it.

No physical location was involved because all data came from the online Scopus database. The main dataset was retrieved on 12 July 2026 for documents published between 2020 and 2025, and the additional verification searches for the fourth research question were run on 20 October 2026.

The population consisted of all Scopus-indexed documents on inquiry-integrated STEM in physics education. The initial search returned 155 documents. The documents were screened in stages adapted from the PRISMA flow for bibliometric studies (Page et al., 2021), leaving a final dataset of 59 documents: 32 journal articles and 27 conference papers.

A document qualified for inclusion when it met three criteria: (1) it addressed STEM or STEAM in an educational context; (2) it focused explicitly on physics learning, teaching, or education; and (3) it contained an inquiry-based pedagogical component. That component was defined operationally as an explicit mention of at least one of these terms: inquiry-based learning, guided inquiry, structured inquiry, open inquiry, inquiry learning, inquiry-based instruction, inquiry-based science education, or argument-driven inquiry. Documents that mentioned STEM or engineering education without an explicit inquiry component were excluded. When a document dealt with general STEM or STEAM, its title and abstract had to describe students practicing at least one inquiry activity, such as posing questions, planning investigations, analyzing evidence, or constructing explanations.

Two reviewers screened the documents independently. Each reviewer judged titles and abstracts against the inclusion criteria and then read the full texts of the documents that remained. The reviewers settled disagreements through discussion, and a third reviewer made the final decision when they could not agree. To check consistency, the reviewers double-coded a subset of 15 documents (25%) and obtained an inter-coder agreement of 93%. The reviewers resolved the remaining discrepancies through discussion.

Data were collected through a structured Scopus search built from three concept blocks: inquiry, STEM, and physics education. Each block contained synonyms, and the Boolean operator AND joined the blocks. Table 1 lists the full query and the limits applied.

Table 1. Scopus search queries (main and verification searches)

Search	Advanced query
Main search, 12 July 2026 (155 documents before limits)	TITLE-ABS-KEY (("inquiry-based learning" OR "inquiry" OR "guided inquiry" OR "inquiry learning" OR "inquiry-based instruction" OR "inquiry-based science education") AND ("STEM" OR "STEAM" OR "integrated STEM" OR "STEM education") AND (physics OR "physics education" OR "physics teaching" OR "physics learning" OR "physics instruction"))
Limits applied to the main search, in order	AND PUBYEAR > 2019 AND PUBYEAR < 2026 (n = 93); then AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) (n = 73); then AND (LIMIT-TO (LANGUAGE, "English")) (n = 72)
Verification search A: main-query	TITLE-ABS-KEY (("inquiry-based learning" OR "inquiry" OR "guided inquiry" OR "inquiry learning"

concepts + electromagnetic induction terms, 20 October 2026	OR "inquiry-based instruction" OR "inquiry-based science education") AND ("STEM" OR "STEAM" OR "integrated STEM" OR "STEM education") AND (physics OR "physics education" OR "physics teaching" OR "physics learning" OR "physics instruction") AND ("electromagnetic induction" OR "Faraday's law" OR "Faraday law" OR "Lenz's law" OR "Lenz law" OR "magnetic induction" OR "induced emf" OR "induced current" OR "magnetic flux" OR electromagnet*)) AND PUBYEAR > 2019 AND PUBYEAR < 2026 Result: n = 1 document
Verification search B: electromagnetic induction terms + inquiry terms, 20 October 2026	TITLE-ABS-KEY (("electromagnetic induction" OR "Faraday's law" OR "Faraday law" OR "Lenz's law" OR "Lenz law" OR "magnetic induction" OR "induced emf" OR "induced current" OR "magnetic flux") AND ("inquiry-based learning" OR inquiry OR "guided inquiry" OR "inquiry learning" OR "inquiry-based instruction" OR "inquiry-based science education" OR "argument-driven inquiry")) AND PUBYEAR > 2019 AND PUBYEAR < 2026 Result: n = 10 documents
Verification search C: electromagnetic induction and applied terms + STEM terms + physics, 20 October 2026	TITLE-ABS-KEY (("electromagnetic induction" OR "Faraday's law" OR "Faraday law" OR "Lenz's law" OR "Lenz law" OR "magnetic induction" OR "induced emf" OR "induced current" OR "induction cooker" OR "induction stove" OR "electric generator" OR transformer) AND (STEM OR STEAM OR "integrated STEM" OR "STEM education" OR "engineering design") AND (physics OR "physics education" OR "physics teaching" OR "physics learning")) AND PUBYEAR > 2019 AND PUBYEAR < 2026 Result: n = 27 documents

Two programs handled the analysis. The first, Bibliometrix (Aria & Cuccurullo, 2017), ran through its R-based Biblioshiny interface. The second, VOSviewer version 1.6.21 (van Eck & Waltman, 2010) , produced a keyword co-occurrence network that served as an independent comparison.

Document selection followed a PRISMA flow adapted for bibliometric studies (Figure 1). The initial search retrieved 155 documents. Restricting the publication window to 2020–2025 left 93 and removed 62 out-of-scope documents. Limiting document types to journal articles (n = 41) and conference papers (n = 32) left 73. The English-language filter reduced that to 72. A final relevance screening against the three inclusion criteria excluded 13 more documents, so the final dataset contained 59 documents (32 journal articles and 27 conference papers).

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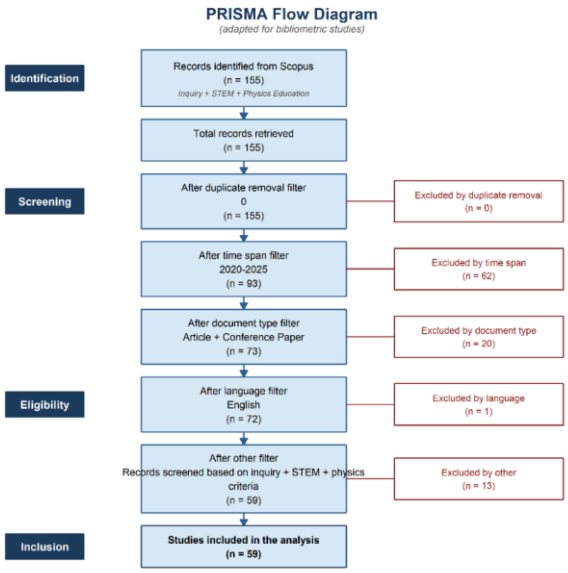


Figure 1. PRISMA flow diagram adapted for bibliometric studies

The analysis ran in two complementary stages. Bibliometrix/Biblioshiny came first and generated these outputs: (a) annual scientific production, (b) most relevant sources, (c) country productivity by affiliation and by corresponding author (SCP and MCP), (d) most globally cited documents, (e) inter-country collaboration networks, (f) a keyword co-occurrence thematic map whose clusters sit according to Callon's centrality and density (Callon et al., 1991), and (g) yearly cumulative keyword trends.

Bibliometrix drew on author keywords and index keywords together. For keyword cleaning, singular and plural forms were merged, spelling variants were unified, and generic stopwords (e.g., "study", "research") were removed. The minimum keyword occurrence was 2, and thematic mapping used Louvain clustering at the default resolution.

In the second stage, VOSviewer 1.6.21 was used to build network, density, and overlay visualizations for comparison. The co-occurrence analysis covered author and index keywords (all keywords) with full counting and a minimum of 3 occurrences per keyword. A thesaurus file merged synonyms, and clustering used the default VOSviewer parameters (resolution = 1.00, minimum cluster size = 1). The resulting network held 21 items in 4 clusters.

To answer the fourth research question, electromagnetic induction and its close synonyms (e.g., Faraday's law, Lenz's law) were searched among all keywords that the two tools produced. Because an absent keyword does not prove an absence of research, three Scopus verification searches were added (Table 1). Search A merged the main query concepts with electromagnetic induction terms, Search B matched electromagnetic induction terms against inquiry terms, and Search C matched electromagnetic induction and applied terms (e.g., generator, transformer) against STEM terms and physics. The titles and abstracts of the retrieved records were read by two authors, who judged whether each treated electromagnetic induction within an inquiry-based or STEM context. The titles, abstracts, and keywords of the 59 analyzed documents were also searched for electromagnetic induction and related terms (induction, induced emf or current, Faraday, Lenz, eddy current, magnetic flux, electromagnet*, generator, transformer). Unless broader verification supports a firmer conclusion, the finding is presented as a gap within the retrieved dataset.

Results

Annual Publication Trend of Inquiry-Integrated STEM in Physics Education

The dataset began with 7 documents in 2020, rose to 12 in 2021, and fell to 5 in 2022. Output recovered steadily from 2023, with 8 papers in 2023, 10 in 2024, and a peak of 17 in 2025 (Figure 2). The compound annual growth rate from 2020 to 2025 was 19.4%. The 59 documents comprised 32 journal articles and 27 conference papers from 36 sources, with an average of 7.39 citations and 4.66 authors per document. International co-authorship appeared in 16.95% of the documents, so most teams worked within a single country instead of in large global consortia.

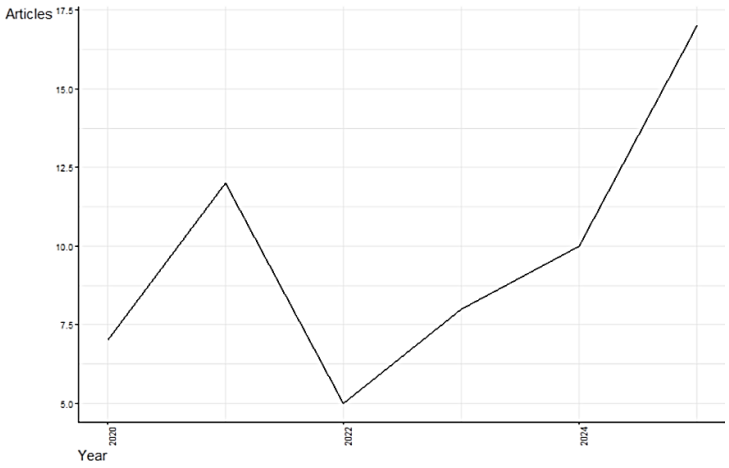


Figure 2. Annual scientific production of inquiry-integrated STEM in physics education (2020–2025)

Source, Country, and Citation-Impact Productivity

Table 2 lists the ten most relevant sources. The *Journal of Physics: Conference Series* ranked first with 7 documents, while *AIP Conference Proceedings* and *Physics Education* each contributed 5 documents. These ten sources together accounted for 33 of the 59 documents, which points to a concentration in conference proceedings and physics-specific outlets.

Table 2. Ten most relevant sources by number of documents

Source	Documents
Journal of Physics: Conference Series	7
AIP Conference Proceedings	5
Physics Education	5
ASEE Annual Conference and Exposition, Conference Proceedings	3
Education Sciences	3
Journal of Research in Science Teaching	2
Journal of Science Education and Technology	2
Physics Education Research Conference Proceedings	2
Physics Educator	2

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Proceedings of the International Astronautical Congress, IAC	2

Table 3 reports country productivity by author-affiliation frequency, a count that includes every author affiliation and can therefore exceed the number of documents. The United States led with a frequency of 51, followed by Indonesia (15), Slovakia (8), and Germany and Italy (7 each). Figure 3 shows the geographic distribution as a choropleth map.

Table 3. Country productivity (author-affiliation frequency), top 15 countries

Country	Frequency
USA	51
Indonesia	15
Slovakia	8
Germany	7
Italy	7
Greece	5
Israel	4
Hungary	3
Malaysia	3
Nigeria	3
Romania	3
Thailand	3
Bulgaria	2
Canada	2
China	2

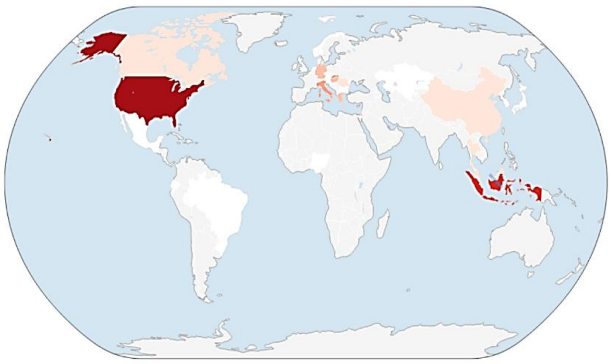


Figure 3. Choropleth map of scientific production by country (Biblioshiny/bibliometrix output)

Table 4 gives a less inflated measure by counting corresponding authors. Indonesia and the United States tied for first with 8 articles each, followed by Slovakia (4) and Israel (3).

All 8 U.S. articles were single-country publications (0% MCP), while 2 of Indonesia's 8 articles (25%) involved international collaboration. With the same number of corresponding-author articles, the U.S. collected far more total citations (120) than Indonesia (17). Germany had the highest average citations per article (51.5), a result driven by Conradty et al. (2020).

Table 4. Country productivity by corresponding author (SCP/MCP) and citation impact, top ten countries

Country	Articles	SCP	MCP	MCP %	Total Citations	Avg. Citations/Article
Indonesia	8	6	2	25	17	2.1
USA	8	8	0	0	120	15
Slovakia	4	3	1	25	8	2
Israel	3	3	0	0	24	8
Germany	2	1	1	50	103	51.5
Italy	2	2	0	0	0	0
Romania	2	1	1	50	29	14.5
Singapore	2	2	0	0	7	3.5
Korea	1	1	0	0	25	25
Netherlands	1	1	0	0	22	22

Table 5 reports cumulative author-affiliation frequency, not the number of documents, for the top five countries. The United States had no affiliation occurrences in 2020, reached 22 in 2021, and stood at 51 in 2024, a value that stayed unchanged in 2025. Because these figures are cumulative, they cannot serve as annual output. Figure 2 shows annual production better. Indonesia's cumulative frequency grew from 2 in 2020 to 10 in 2021 and then rose in small steps to 15 in 2025. Slovakia showed a later and sharper rise: no affiliation occurrences appeared until 2023, followed by 1 in 2024 and 7 in 2025, for a cumulative total of 8. A single new research group or project entering during that period could explain this, although the analysis did not test this explanation.

Table 5. Cumulative country production over time for the top five countries

Country	2020	2021	2022	2023	2024	2025
USA	0	22	38	44	51	51
Indonesia	2	10	10	11	14	15
Slovakia	0	0	0	0	1	8
Germany	1	1	2	7	7	7
Italy	2	2	4	4	6	7

The inter-country collaboration network (Table 6) is sparse and regional. Indonesia and Malaysia formed the strongest link with two joint documents. Four other ties (Indonesia-

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Thailand, Indonesia-Canada, USA-Indonesia, and USA-Norway) each involved one document. A separate internal cluster of Central and Eastern European countries also appeared. These patterns could reflect specific regional projects instead of broad regional integration, but the dataset does not test this idea.

Table 6. Inter-country collaboration ties from the Biblioshiny collaboration network

From	To	Frequency
Indonesia	Malaysia	2
USA	Indonesia	1
USA	Norway	1
Indonesia	Thailand	1
Indonesia	Canada	1
Thailand	Canada	1
Guatemala	Mexico	1
Germany	Greece	1
Austria / Bulgaria / Czech Rep. / Denmark / Hungary / Slovenia / Slovakia / Romania	(internal cluster, 8 countries)	1 each tie

Table 7 lists the ten most globally cited documents. The most cited, by Conradty et al. (2020), studied creativity in STEAM modules in relation to self-efficacy and motivation and received 82 citations. Solomon et al. (2022) came next with 57 citations for a study of movement-based physics learning within STEM, and Price et al. (2021) drew 45 citations for work on a faculty online learning community that supports implementation of an inquiry-based curriculum.

Table 7. Ten most globally cited documents

Document	DOI	TC	TC/Year	NTC
Conradty et al., (2020), Educ. Sci.	10.3390/educsci10030070	82	11.7	4.38
Solomon et al., (2022), J. Learn. Sci.	10.1080/10508406.2021.2023543	57	11.4	3.65
Price et al., (2021), Int. J. STEM Educ.	10.1186/s40594-021-00281-w	45	7.5	4.58
Chiriacescu et al., (2020), Rom. Rep. Phys.	—	29	4.1	1.55
Jang & Choi, (2025), J. Sci. Educ. Technol.	10.1007/s10956-024-10173-1	25	12.5	10.9
Dmoshinskaia et al., (2021), J. Sci. Educ. Technol.	10.1007/s10956-020-09884-y	22	3.7	2.24

Flegr et al., (2023), Learn. Instr.	10.1016/j.learninstruc.2023.101778	21	5.2	3.23
Kapon et al., (2021), J. Res. Sci. Teach.	10.1002/tea.21654	19	3.2	1.93
Odden et al., (2023), J. Res. Sci. Teach.	10.1002/tea.21821	19	4.8	2.92
Wu et al., (2022), ACM Int. Conf. Proc. Ser.	10.1145/3514262.3514313	19	3.8	1.22

Thematic Structure: Thematic Map and Keyword Co-occurrence

The thematic map (Figure 4, Table 8) splits the keyword network into ten clusters by centrality and density. Two clusters sat in the motor-theme quadrant: students (density 74.18; centrality 4.84; 73 occurrences) and engineering education (density 264.99; centrality 4.51; 59 occurrences). Both are dense and well connected to other clusters, and they form the main axis of the network. STEM education (density 43.63; centrality 1.90; 42 occurrences) fell in the basic-theme quadrant, which means strong connections with lower internal density. Active learning, inquiry, and scientific inquiry occupied the niche-theme quadrant, and innovative projects, the smallest cluster at 2 occurrences, lay at the lower boundary. The clusters rest on keyword co-occurrence, so their positions describe the bibliometric network and say nothing definitive about the maturity or instructional effectiveness of a topic.

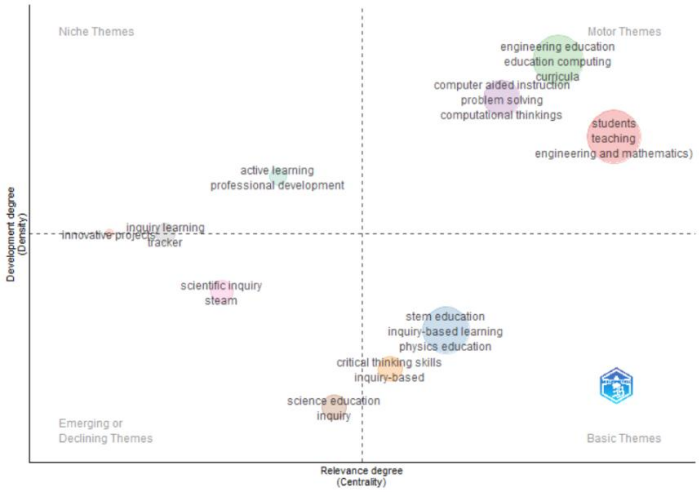


Figure 4. Thematic map of inquiry-integrated STEM research in physics education (Callon centrality–density, Louvain clustering)

Table 8. Centrality, density, and keyword-occurrence frequency of each cluster in the thematic map

Cluster (top keyword)	Callon Centrality	Callon Density	Keyword-Occurrence Frequency
Students	4.84	74.18	73
engineering education	4.51	264.99	59
computer-aided instruction	3.8	96.83	18

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STEM education	1.9	43.63	42
critical thinking skills	1.19	37.5	7
science education	0.96	33.33	7
scientific inquiry	0.46	43.75	6
inquiry learning	0.33	50	5
active learning	0.75	62.5	4
innovative projects	0.25	50	2

VOSviewer found 21 keywords arranged in 4 clusters (Figure 5), with 103 links and a total link strength of 217. Cluster 1 (7 keywords) held critical thinking skills, inquiry-based learning, physics education, STEM, and STEM education; Cluster 2 (5) held computational thinking, education computing, inquiry, and science education; Cluster 3 (5) held curricula, engineering education, scientific inquiry, and students; and Cluster 4 (4) held problem-solving, STEM, teachers, and teaching. In general, these clusters agree with the Bibliometrix results.

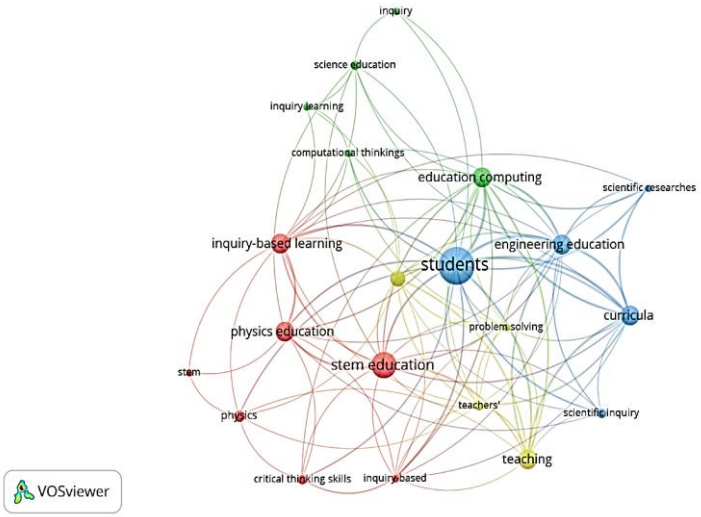


Figure 5. VOSviewer keyword co-occurrence network (21 items, 4 clusters)

Figure 6 shows the VOSviewer density visualization. Students form the densest node, surrounded by engineering education, education computing, STEM education, and curricula. The overlay visualization (Figure 7) colors nodes by mean publication year and shows a clear temporal gradient. Keywords on teaching and science education have an earlier mean year (about 2022), whereas engineering education, curricula, and STEM education have a later one (about 2023 to 2024). This pattern agrees with the cumulative keyword trend in Figure 8 and indicates that the applied, engineering-oriented side of inquiry-integrated STEM has become more visible over the last two to three years.

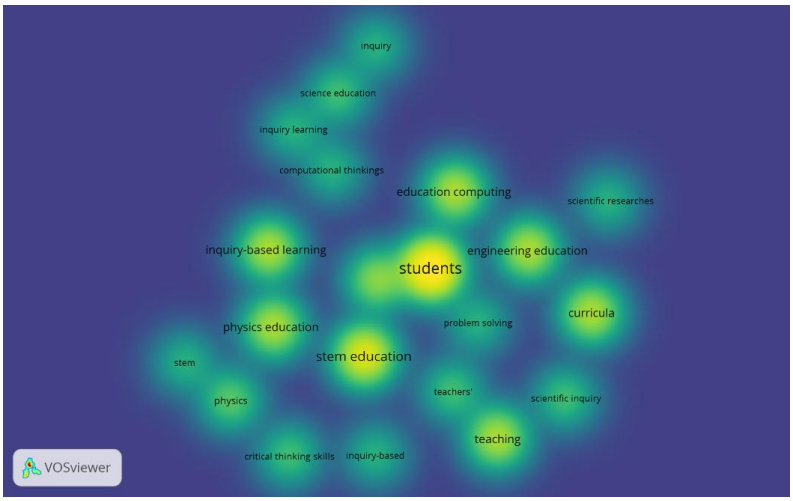


Figure 6. VOSviewer density visualization for keyword co-occurrence

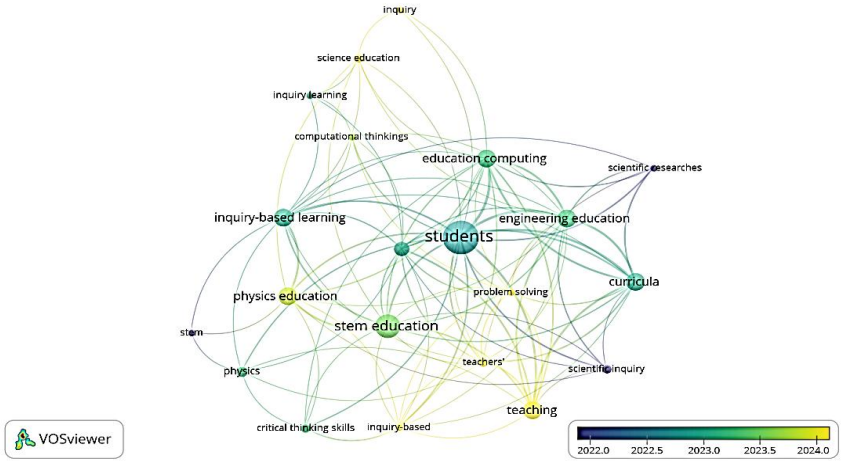


Figure 7. VOSviewer overlay visualization for keyword co-occurrence, colored by mean publication year

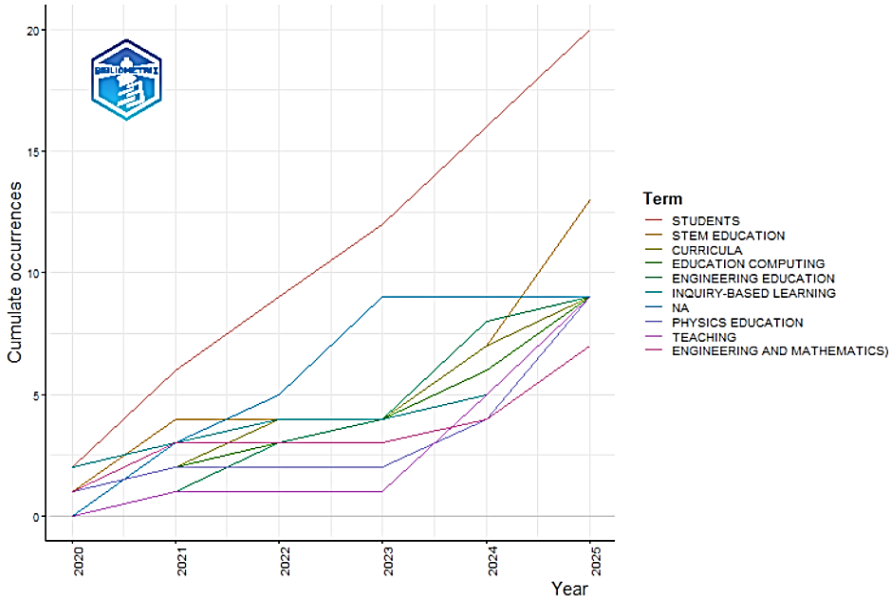


Figure 8. Cumulative occurrence of the ten most frequent keywords, 2020–2025

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The Electromagnetic Induction Research Gap

None of the 250 keyword nodes in the Bibliometrix thematic map, the full keyword-frequency list (366 terms), or the 21 VOSviewer keywords contained electromagnetic induction. Synonyms such as Faraday's law and Lenz's law did not appear either, and the term belonged to none of the ten thematic clusters or the four VOSviewer clusters. The closest terms in the dataset, atmospheric chemistry and optical radar, fall under different physics sub-fields. The titles, abstracts, and author and index keywords of the 59 documents were also searched for electromagnetic induction, Faraday's law, Lenz's law, magnetic induction, eddy current, induced emf or current, magnetic flux, electromagnet*, generator, and transformer, and no document matched.

Because a document can discuss a topic without listing it as a keyword, a missing keyword is only a weak indicator. Three wider verification searches were run in Scopus (Table 1): Search A (main-query concepts plus electromagnetic induction terms) returned 1 document, Search B returned 10, and Search C returned 27, which makes 38 records with no overlap. The 59 analyzed documents include none of them. Titles, abstracts, and keywords of the 38 records were screened for electromagnetic induction in an inquiry-based or STEM context, and seven documents were kept (Table 9). Those seven used terms such as magnetic induction, Faraday's law, and eddy currents, and five were conference papers on STEM, STEAM, or project-based learning. The remaining 31 records did not deal with teaching or learning electromagnetic induction through inquiry or STEM; some were engineering or computing studies where "generator" or "transformer" names equipment or models, and others were laboratory studies of electromagnetic phenomena with no inquiry or STEM component. Related work thus exists outside the analyzed dataset, while the dataset itself held no document on electromagnetic induction. The finding is a gap in the visibility of the topic within the analyzed dataset, and it holds only for Scopus and the search terms used.

Table 9. Documents retrieved in the verification searches that address electromagnetic induction in a STEM or inquiry-based context (n = 7)

Document	Source	STEM or inquiry-based approach and topic
Parno et al. (2020)	J. Phys.: Conf. Ser.	Project-based learning (PjBL)-STEM; problem-solving skills; electromagnetic induction (quasi-experiment)
Parno et al. (2021)	J. Phys.: Conf. Ser.	PjBL-STEM with a Faraday flashlight project; problem-solving skills
Amin et al. (2021)	J. Phys.: Conf. Ser.	AR-STEAM worksheet; need analysis among students who had studied electromagnetic induction
Bozzo et al. (2022)	Eurasia J. Math. Sci. Technol. Educ.	Inquiry-based experimental sequence (Atwood's machine); Faraday–Neumann–Lenz law
Muhammad et al.	AIP Conf. Proc.	STEM-based augmented reality

(2024)		media on magnetic induction; creative thinking skills
Shobah et al. (2024)	AIP Conf. Proc.	STEAM learning medium (generator windmill with dynamo torch); energy conversion
Hong (2025)	New Phys.: Sae Mulli	Inquiry-based activity on magnetic braking (eddy currents, Faraday's law)

Discussion

The upward trend, despite the 2022 dip, points to a rise in Scopus-indexed documents on inquiry-integrated STEM in physics education between 2020 and 2025. A six-year window and small annual counts do not support the conclusion that the field is still growing or has saturated. Several explanations could account for the fluctuations, and this analysis tested none of them. The 2021 increase may reflect the pandemic-era push toward remote and digital inquiry, and the 2022 decline may reflect a post-pandemic slowdown in educational technology publishing or indexing delays. Testing these ideas would require content analysis or a comparison with publication trends in neighboring fields. The data do show a steady recovery from 2023 onward that ended with the highest output in 2025.

Publications concentrate in the *Journal of Physics: Conference Series*, *AIP Conference Proceedings*, and *Physics Education*, a pattern common in bibliometric research on STEM physics. Conference proceedings may serve as fast-turnaround outlets for early-stage instructional innovations, while specialist journals such as *Physics Education* may carry more developed findings, although this study did not test the idea. The prominence of the United States and Indonesia could reflect the long-established physics education research tradition in the United States and the fast-growing STEM education community in Indonesia. Because the data cover only author-affiliation frequencies and corresponding-author counts, this explanation stays a hypothesis. The sparse, regional collaboration network suggests that inquiry-integrated STEM research currently develops through regional partnerships or specific projects, such as those linking Indonesia, Malaysia, Thailand, and a Central European consortium, more than through large-scale international collaboration.

Conradty et al. (2020) and Solomon et al. (2022) both connect creative, movement-based, or arts-infused (STEAM) approaches with motivation and self-efficacy. Price et al. (2021) underline the importance of professional development infrastructure, such as faculty learning communities, for sustaining inquiry-based curriculum reform at scale. This agrees with the view that putting inquiry-integrated STEM into practice depends on the support system for teachers and lecturers as well as on the instructional model, although a bibliometric analysis cannot establish a causal relationship.

The thematic map places students and engineering education in the motor-theme quadrant, so these clusters are dense and connected to other clusters across the network. STEM education sits in the basic-theme quadrant, with strong connections but lower internal density. This position suggests that STEM works as an umbrella framework linked to more specific themes, such as engineering design and computer-aided instruction, instead of a narrow standalone topic. Active learning, inquiry learning, and scientific inquiry appear as niche themes. Inquiry defines the field conceptually, yet its keywords form small clusters with

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few links to the rest of the network. That may leave room for work on the mechanisms of inquiry in STEM physics learning, but the thematic map cannot show whether such work is scarce or simply indexed under other keywords.

The specific term *electromagnetic induction* was missing from the primary keyword frequency data, the thematic and co-occurrence networks, and the titles and abstracts of the 59 documents, which suggested a potential gap. The targeted verification searches, however, found seven additional documents that combine electromagnetic induction (or related concepts such as magnetic induction, Faraday's law, and eddy currents) with inquiry-based or STEM approaches. One study used augmented reality for magnetic induction to improve creative thinking skills (Muhammad et al., 2024) and another applied project-based learning to improve problem-solving on this topic (Parno et al., 2021).

This finding refines the reading of the gap. Researchers have studied the topic, but the analyzed dataset does not contain that work, and related pedagogical studies exist outside it, several under terms such as magnetic induction. Electromagnetic induction remains conceptually demanding because learners must coordinate magnetic fields, flux, and Lenz's law at once (Guisasola et al., 2013; Jelicic et al., 2017; Xie et al., 2025). One untested hypothesis holds that inquiry-integrated STEM innovation has gathered around topics that adapt more easily to project-based learning (e.g., mechanics, optics, aerospace applications), which leaves electromagnetic induction under-represented in the analyzed dataset.

Filling this gap could advance Sustainable Development Goal 4 on quality education, which asks for effective, equitable, and evidence-based learning environments (United Nations, 2015). For future research, studies could design and empirically test inquiry-based STEM interventions on electromagnetic induction, for example engineering-design tasks built around induction stoves, generators, or transformers. These are suggestions for future work and not outcomes established by the bibliometric analysis.

This study has several limitations. It relies only on the Scopus database, so relevant work indexed in Web of Science, ERIC, or other databases may be missing. The search strategy used the terms inquiry, STEM, and physics education and may have missed studies that address electromagnetic induction through everyday applied terms without the words "inquiry" or "STEM." Because the main analysis rests on keyword-level indicators, it cannot separate topics that are truly unstudied from topics studied under different terminology. Cluster positions in the thematic map describe the keyword network and reveal nothing about the maturity or instructional effectiveness of a topic. The explanations offered for publication trends remain untested hypotheses. Future verification research should broaden the search terms and use multiple databases.

Conclusion

This bibliometric analysis mapped 59 Scopus-indexed documents on the integration of inquiry into STEM for physics education from 2020 to 2025. Annual output in this dataset fluctuated, dipped temporarily in 2022, and reached its highest count in 2025. Specialist physics journals and conference proceedings carried most of the documents, and the United States and Indonesia had the highest author-affiliation frequencies. In the keyword network, students and engineering education occupied the motor-theme quadrant, and STEM education acted as a broad basic theme.

For the fourth research question, none of the 59 documents in the dataset used electromagnetic induction or a closely related term in its title, abstract, or keywords. The targeted Scopus verification searches found seven more documents outside the dataset that

paired electromagnetic induction with STEM or inquiry-based approaches. The topic is under-represented in the analyzed dataset yet present in the wider literature, and the finding is limited to Scopus and the search terms used. The conclusions also carry the limitations noted above: reliance on a single database, keyword-level indicators, and untested explanations for publication trends. These findings should therefore not be generalized beyond the analyzed dataset.

The findings offer researchers a first map of Scopus-indexed work in this field. Future studies could build and pilot inquiry-based STEM learning units on electromagnetic induction, borrowing the engineering-design, creativity, or movement approaches reported in existing literature and testing their effects on student learning. Such work aligns with Sustainable Development Goal 4 on quality education. These implications serve as suggestions for future work, and the bibliometric analysis itself does not establish them as outcomes.

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