Al-Bidayah : Jurnal pendidikan dasar Islam
Volume 17, Number 2, December 2025
ISSN : 2549-3388 (online)
Available online at https://ejournal.uin-suka.ac.id/tarbiyah/albidayah
Submitted: September 17, 2025, Accepted: December 15, 2025

Publication Trends on Higher-Order Thinking Skills and Science Process Skills in Elementary Schools (1992–2023): A Bibliometric Analysis of Science Education

Irham Nugroho[1], Insih Wilujeng[2], Pujaningsih[3], Muis Sad Iman[4], Putri Nadya Mahesawati[5]

Muhammadiyah University of Magelang, Indonesia [1,4,5], Universitas Negeri Yogyakarta, Indonesia[2,3]
E-mail: irhamnugroho@unimma.ac.id[1], insih@uny.ac.id[2], pujaningsih@uny.ac.id[3], msi71@unimma.ac.id[4], putdyaah@gmail.com[5]

DOI: 10.14421/al-bidayah.v17i2.12039

Abstract

This study examines publication trends and thematic developments in research on Higher-Order Thinking Skills (HOTS) and Science Process Skills (SPS) in elementary science education. A bibliometric approach was employed to analyze Scopus-indexed publications from 1992 to 2023, using title, abstract, and keyword searches with queries such as ("Higher Order Thinking Skills" AND "Science Process Skills" AND "elementary science education"). The data were processed using the Bibliometrix package and BiblioShiny interface in RStudio to map growth patterns, identify influential sources, leading countries, and emerging research themes related to the integration of HOTS and SPS. The results show a significant increase in publications since 2014, with 322 documents identified. The Journal of Physics: Conference Series emerged as the leading source, while Indonesia and Malaysia were the top contributing countries. Thematic analysis revealed dominant clusters around inquiry learning, critical thinking, and digital assessment, with a noticeable shift towards applied instructional and assessment models that combine HOTS and SPS. This reflects the growing alignment of research with 21st-century education reforms emphasizing inquiry-based and problem-solving skills. The findings suggest a strong integration of HOTS and SPS in science education, but also highlight gaps in long-term classroom implementation, particularly in elementary school contexts. This study underscores the need for curriculum frameworks and teacher professional development programs focused on effectively integrating HOTS and SPS into elementary science education.
Keywords: science process skills; hots; a bibliometric map; scopus data; rstudio

Introduction

Educators today face increasingly complex challenges, including managing large classes, integrating curricula effectively, and applying competency-based assessment methods (Ganguly et al., 2023). These conditions demand innovation in digital learning development that not only enhances creativity and personal growth but also prepares students to adapt to rapidly evolving technological changes (Manurung, Purwadi, & Sugiharto, 2022). Furthermore, the concept of meaningful learning-defined by active student participation and the development of effective learning agents-requires a balance

between instructional needs and existing classroom limitations while also addressing students' emotional well-being as a key contributor to academic success (Napaporn et al., 2023).

The integration of information and communication technologies in learning, particularly within STEM education, has become an urgent priority in the 21st century (Pathoni, Asyhar, Maison, & Huda, 2022; González-pérez & Ramírez-montoya, 2022). Technology offers significant potential for enhancing interaction, exploration, and student competency, yet the main challenge lies in utilizing this accessibility to create effective and engaging learning experiences (Eady, Michelle J. and Lockyer, 2013; Rapanta, Botturi, Goodyear, Guàrdia, & Koole, 2020). In this context, science education is expected to undergo a transformation that emphasizes critical thinking, problem-solving, and the application of scientific knowledge to real-world situations (Nugroho et al., 2021). The Merdeka Curriculum seeks to address these needs through discovery-based and problem-solving learning experiences that strengthen students' higher order thinking skills (HOTS) and science process skills (SPS), supported by educational technology (Jeronen et al., 2016).

Recent studies in Indonesian primary and Islamic elementary education emphasize the importance of contextual, inquiry-based, and student-centered science learning as a foundation for developing higher-order cognitive skills and scientific inquiry (Susilawati et al., 2025). Research published in national journals of Islamic elementary education has highlighted that science instruction in Madrasah Ibtidaiyah still requires stronger integration between inquiry activities, critical thinking, and assessment practices to meet current curriculum demands (Agustina et al., 2020; Murtono, 2009).

Designing instruction that integrates technology, inquiry, collaboration, and scientific discussion is essential for fostering HOTS-oriented learning in the 21st century (Reta, 2012). Through such approaches, education is expected to cultivate students who are not only knowledgeable in science but also adaptive, creative, and able to solve complex future problems (Windschitl, 2009).

HOTS plays a crucial role in enabling students to achieve higher levels of analysis, evaluation, and creativity, particularly in environmental and natural science contexts (Ragab et al., 2024). It has become a fundamental requirement for preparing students to tackle complex challenges, as highlighted in national and international educational

frameworks (Ichsan et al., 2019; Musa & Meor Samsudin, 2021). According to the revised Bloom's taxonomy, HOTS encompasses analytical, evaluative, and creative thinking, and requires conceptual, procedural, and metacognitive knowledge dimensions (Retnawati, Djidu, Kartianom, Apino, et al., 2018). Modules and instructional models that integrate STEM and project-based learning have been shown to significantly improve these higher-level competencies (Keleman, 2021).

However, despite its importance, empirical evidence consistently shows that students' HOTS performance particularly in elementary schools remains low. Ichsan et al (2019) demonstrated that HOTS achievement is insufficient across all schooling levels, with the most substantial gaps emerging in early grades where foundational thinking skills should be strengthened. Recent findings from HOTS-oriented E-PjBL models (Rati et al., 2023) demonstrate improvements in 4C abilities and science learning outcomes, yet such innovations are still rarely implemented in MI/SD settings, where instruction often prioritizes recall over analytical inquiry. These conditions underscore the urgency of developing updated and evidence-based approaches to strengthen HOTS and SPS at the elementary level (Ragab et al., 2024).

Strengthening science process skills is equally essential, as SPS not only enhances conceptual understanding but also fosters active participation in scientific inquiry (Kriswantoro et al., 2021; Sholahuddin et al., 2020). Early exposure to SPS-supported learning, especially when integrated with STEM education, has been shown to elevate students' scientific reasoning and prepare them for advanced 21st-century competencies (Darmaji et al., 2020; Agussuryani et al., 2022).

The literature therefore indicates the need for a comprehensive and systematically designed approach to developing HOTS within SPS, particularly in elementary science learning. Several supporting factors contribute to the success of HOTS-based instructional designs, including teachers' pedagogical readiness, the availability of digital tools, inquiry-based models, and assessment systems aligned with higher-order competencies (Siregar, 2025). Integration of these components has been shown to improve analytical reasoning, scientific investigation skills, and students' ability to apply concepts in real contexts (Hidayat et al., 2024). Mapping these developments is essential to better understand how HOTS and SPS research has evolved and to guide future learning innovations (Elvira et al., 2025).

Addressing this need, the novelty of the present study lies in conducting a comprehensive bibliometric analysis of Scopus-indexed publications from 1992–2023 using Bibliometrix and BiblioShiny in RStudio®. This analysis identifies emerging trends, thematic clusters, influential authors, and research trajectories related to HOTS and SPS in elementary science education. The findings are expected to generate valuable insights for teachers, curriculum designers, and policymakers, supporting the development of instructional strategies and assessment systems that effectively foster HOTS and SPS in primary schools.

Although numerous studies have examined Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) in various educational settings, the evolution, distribution, and thematic direction of research in the MI/SD context remain insufficiently explored in a systematic manner. The research interest of this study lies in mapping how HOTS and SPS have been discussed, connected, and developed across scientific publications, particularly in response to increasing demands for inquiry-based and competency-oriented science learning at the elementary level. This interest is driven by empirical data showing a rapid increase in HOTS-SPS publications after 2014, alongside persistent evidence of low HOTS performance among elementary students, which highlights a critical gap between research growth and classroom implementation. By employing a bibliometric approach, this study maps research trends, thematic clusters, and collaboration patterns to reveal how HOTS and SPS are positioned, integrated, or treated separately within science education literature. The novelty of this study lies in its ability to synthesize large-scale publication data into an evidence-based overview that clarifies research directions, identifies underexplored themes, and provides a data-driven foundation for future instructional design, assessment development, and teacher professional learning in elementary science education. In this way, existing research is positioned not merely as archival information but as a structured knowledge base that informs and supports innovation in HOTS-and SPS-oriented science learning.

Methods

This study employed a systematic literature review (SLR) combined with a bibliometric approach to map publication trends, intellectual structures, and thematic developments related to Higher Order Thinking Skills (HOTS) and Science Process Skills

(SPS) in elementary science education. The primary objective of this method was to provide an evidence-based overview of how HOTS-SPS research has evolved over time, including growth patterns, influential authors and sources, collaboration networks, and dominant research themes. Bibliometric analysis was selected because it allows for a quantitative, objective, and replicable examination of scientific literature, enabling the identification of research trajectories and knowledge structures within a specific field (Donthu et al., 2021).

The Scopus database was used as the primary data source due to its wide coverage of high-quality, peer-reviewed international publications and its standardized bibliographic metadata, which are essential for citation analysis and network mapping. Bibliometric data were retrieved in March 2023 using an expanded Boolean search strategy to ensure alignment with the elementary education focus of the study. The search query applied was TITLE-ABS-KEY ("science process skills" AND "higher order thinking skills" AND ("elementary school" OR "primary school" OR "basic education" OR "elementary education" OR "primary education")), with a publication time span from 1992 to 2023. The search was limited to the subject areas of Education, Social Sciences, and Psychology, and included journal articles, review papers, conference papers, and book chapters. Inclusion criteria required that publications be Scopus-indexed, written in English, directly related to HOTS and SPS in elementary or primary education contexts, and published in peer-reviewed sources. Non-English documents, non-peer-reviewed publications, duplicated records, and studies outside educational or elementary-level contexts were excluded. From an initial retrieval of 423 records, 376 documents were retained after screening.

Data analysis was conducted using the Bibliometrix R-package (version 4.1) and its web-based interface, BiblioShiny, in RStudio® (Aria & Cuccurullo, 2017). The analysis integrated three complementary bibliometric perspectives. First, performance analysis was applied to examine annual publication growth, total publications, citation counts, h-index values, and country productivity. Second, behavioral indicators were used to analyze authorship patterns, co-authorship networks, and international collaboration rates. Third, bibliometric network analysis was conducted through keyword co-occurrence, co-citation analysis, and bibliographic coupling to explore the conceptual and intellectual structure of HOTS-SPS research. Both descriptive and inferential bibliometric

techniques were employed, including frequency distribution analysis, annual trend analysis, Lotka's Law for author productivity, Bradford's Law for journal dispersion, and thematic evolution mapping (Agbo et al., 2021).

To visualize and interpret the bibliometric structures, maps were generated using normalization techniques such as Association Strength and Cosine Similarity, followed by clustering algorithms including Walktrap and Louvain modularity to identify thematic and collaboration clusters. Thresholds were applied to enhance interpretability and analytical rigor, including a minimum of five publications per author, three keyword occurrences, and five documents per country or institution. The overall bibliometric workflow consisted of three main stages: data collection, data screening, and data analysis (Figure 1). This workflow from data retrieval and cleaning to statistical computation and visualization was conducted in accordance with established bibliometric research standards to ensure transparency, validity, and replicability of the findings.

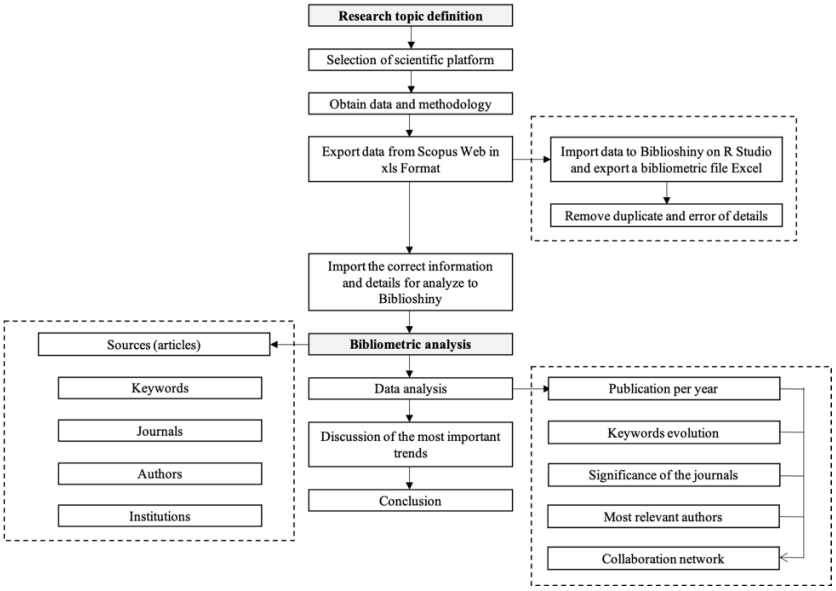

Figure 1. Bibliometric analysis workflow
(Source: Adapted from Bibliometrix framework, 2023)

Result

Using the Bibliometrix and BiblioShiny packages on Scopus-indexed publications from 1992 to 2023, this study identified a total of 376 documents authored by 954 researchers across 94 publication sources. These data represent the final dataset obtained

after a systematic pre-data search and screening process, including keyword formulation, subject area filtering, and duplication removal.

The descriptive bibliometric indicators were employed as the first stage of data analysis to establish a general profile of HOTS–SPS research development. Table 1 summarizes the core characteristics of the dataset, including publication timespan, document types, authorship patterns, and keyword distribution. An annual growth rate of 6.22% indicates a steady increase in scholarly attention toward the integration of Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS), particularly in response to global shifts toward inquiry-based and competency-oriented science education.

From a theoretical perspective, the relatively low average citation rate (3.714 citations per document) suggests that HOTS–SPS research remains an evolving field, with many studies focusing on applied classroom innovations rather than established theoretical consolidation. This pattern is consistent with the nature of educational research that emphasizes contextual implementation and instructional experimentation, especially at the elementary school level (Brown, 1992).

Table 1. Main information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1992:2023
Sources (Journals, Books, etc)	94
Documents	322
Annual Growth Rate %	6,22
Document Average Age	3,33
Average citations per doc	3,714
References	9657
DOCUMENT CONTENTS	
Keywords Plus (ID)	942
Author's Keywords (DE)	508
AUTHORS	
Authors	954
Authors of single-authored docs	13
AUTHORS COLLABORATION	
Single-authored docs	15
Co-Authors per Doc	3,62
International co-authorships %	7,764
DOCUMENT TYPES	
Article	122

Description	Results
conference paper	192
conference review	2
Editorial	1
Review	4
short survey	1

(Source: Scopus/Bibliometrix export, 2023)

Source Development Over Time

Figures 2 and 3 illustrate the longitudinal trend of publications and citation averages from 1992 to 2023. The growth of publications remained low and irregular before 2014 but began to increase rapidly thereafter, marking a significant rise in global attention to HOTS–SPS research.

The pattern of average citations per year shows that although publication output has grown consistently, the field is still expanding and has not yet reached full maturity in terms of citation depth and global influence.

The surge in publications after 2014 reflects a growing alignment between HOTS-SPS research and international science education reforms emphasizing inquiry, problem solving, and authentic assessment. This trend suggests that HOTS and SPS are increasingly treated as complementary competencies, where higher-order cognitive processes are developed through structured scientific investigation.

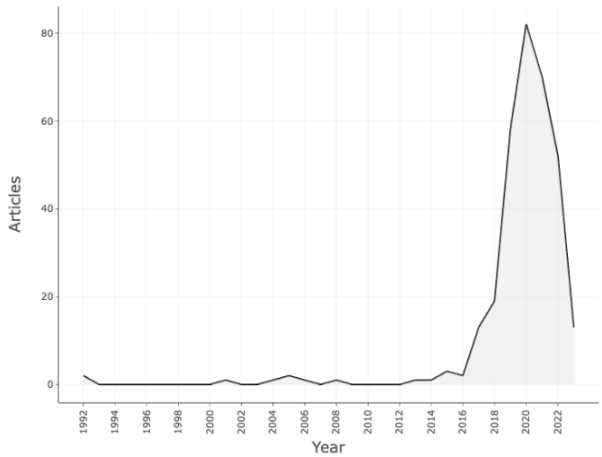

Figure 2. Accumulation of articles over time

(Source: Scopus/Bibliometrix export, 2023)

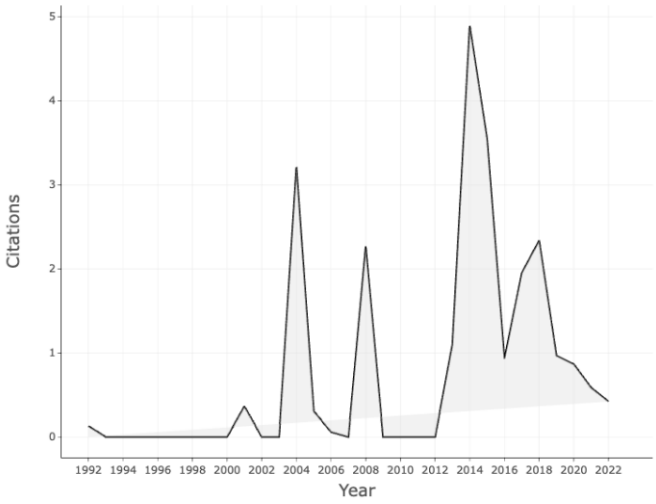

Figure 3. Average article citations per year

(Source: Scopus/Bibliometrix export, 2023)

Source Contribution and Influence

To identify major publication venues, source analysis was conducted to examine journals and conference proceedings that published the most relevant and influential works. Publications were distributed across approximately 200 sources, with the top twenty contributing the highest citation counts and document outputs.

Figures 4–6 display the citation impact, dynamic trends, and h-index of these leading outlets. The Journal of Physics: Conference Series and AIP Conference Proceedings were among the most productive sources, indicating their central role in disseminating studies on HOTS and science process skills. Collectively, the top 20 sources accounted for more than half of the total citations within the dataset.

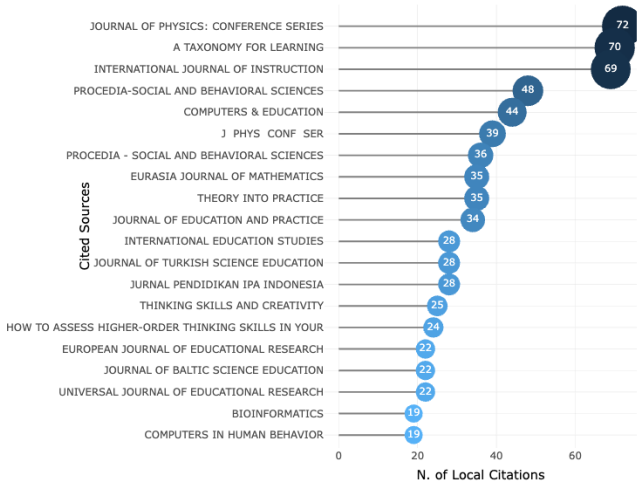

Figure 4. Source impact by total citations

(Source: Scopus/Bibliometrix export, 2023)

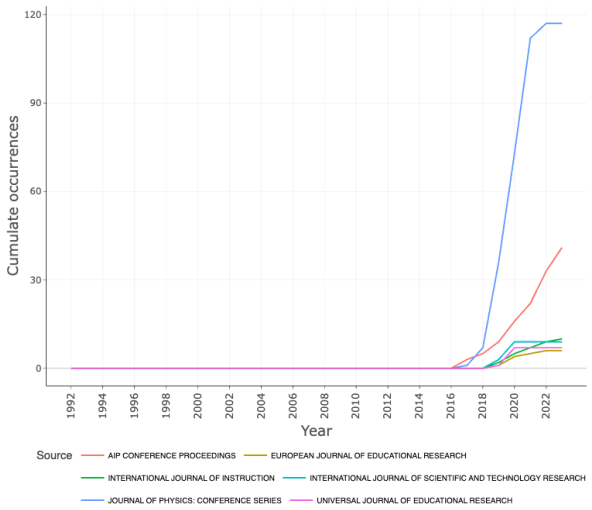

Figure 5. Source dynamics over time

(Source: Scopus/Bibliometrix export, 2023)

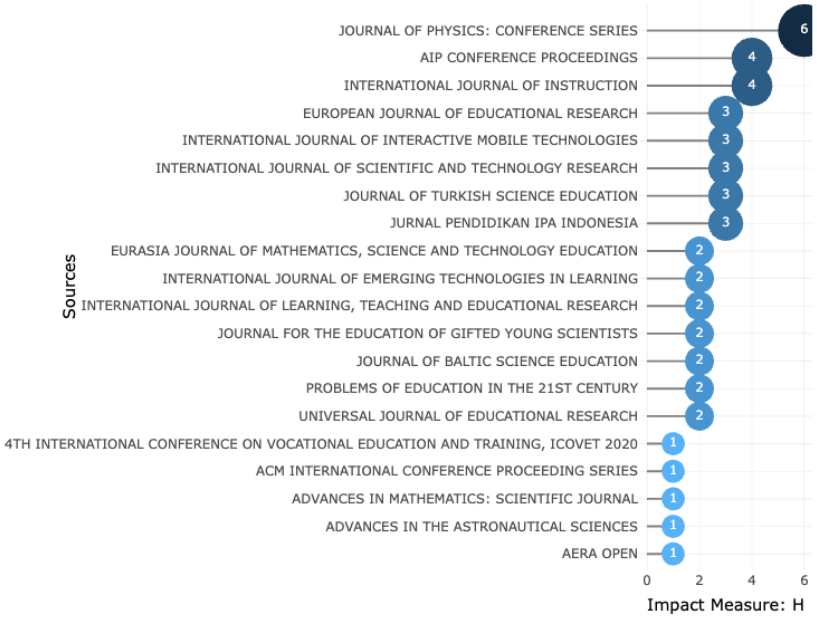

Figure 6. Source h-index within the dataset

(Source: Scopus/Bibliometrix export, 2023)

Author Productivity and Impact

The productivity and impact of contributing authors were analyzed to identify leading scholars who have shaped the development of Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) research. A total of 954 authors contributed to 376 documents, indicating broad scholarly engagement in this field, although only a limited number of authors demonstrated sustained productivity through multiple

publications. This pattern reflects the interdisciplinary nature of HOTS-SPS research, which attracts contributions from diverse educational and scientific backgrounds.

Table 2 presents the most productive and influential authors based on publication count, citation impact, and h-index. Authors with higher citation metrics tend to focus on theoretical frameworks and empirical models that integrate HOTS cognitive dimensions such as analysis, evaluation, and creation with core science process skills, including observation, hypothesis formulation, data interpretation, and scientific reasoning. This finding aligns with established theories suggesting that the development of higher-order thinking is closely linked to students' engagement in authentic scientific inquiry processes (Antonio & Prudente, 2024).

Furthermore, the temporal distribution of author productivity (Figure 7) indicates that influential contributions have increased after 2014, corresponding with the global shift toward inquiry-based, competency-oriented science education. From a theoretical perspective, this trend supports the view that HOTS functions as the cognitive foundation of SPS, while SPS operationalizes HOTS through hands-on investigation and problem-solving activities. Therefore, the authors identified in this analysis can be considered key contributors to the conceptual integration of HOTS and SPS, providing empirical and theoretical references that inform instructional design, assessment development, and teacher professional learning in elementary science education.

Table 2. Top authors

Rangking	Authors	PY_start	NP	TC	h_index
1	Abdullah Ah	2015	2	83	9,222
2	Abdullah Ah	2017	2	47	6,714
3	Abdullah Ah	2019	1	0	0
4	Abdullah Ah	2020	1	2	0,5
5	Abdullah Ah	2021	1	6	2
6	Abdullah Ah	2023	1	0	0
7	Ali Df	2017	1	47	6,714
8	Ali Df	2020	1	2	0,5
9	Ali Df	2021	1	6	2
10	Ali Df	2023	1	0	0
11	Amalia R	2020	3	6	1,5
12	Amalia R	2023	1	0	0
13	Apino E	2017	1	61	8,714
14	Apino E	2018	2	111	18,5
15	Dwandaru Wsb	2019	1	4	0,8

16	Dwandaru Wsb	2020	2	24	6
17	Dwandaru Wsb	2021	1	7	2,333
18	Fauzan A	2020	2	15	3,75
19	Fauzan A	2021	1	0	0
20	Hamzah Mh	2015	1	15	1,667

(Source: Scopus/Bibliometrix export, 2023)

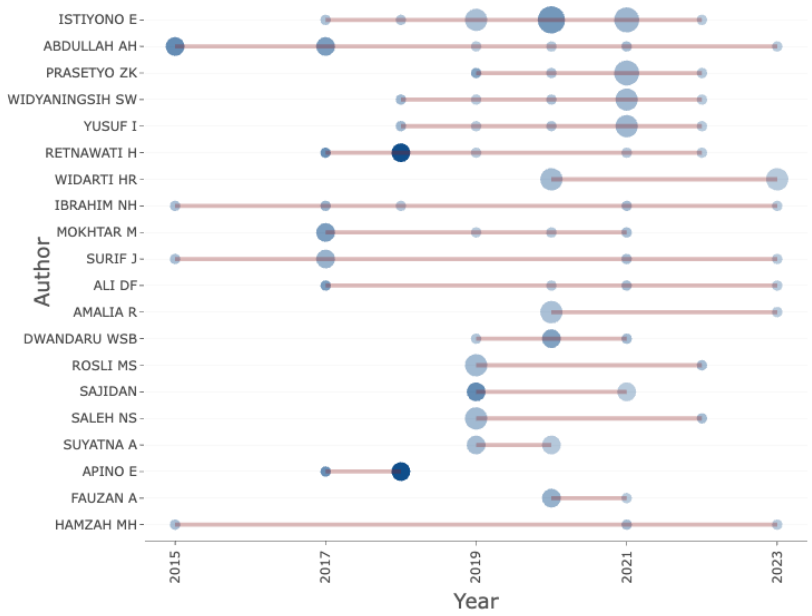

Figure 7. Top author productivity and citations per year

(Source: Scopus/Bibliometrix export, 2023)

Most-Cited Documents

Highly cited documents provide insight into the foundational studies and theoretical frameworks that have shaped HOTS–SPS research. Figure 8 presents the top globally cited publications, highlighting key works that have significantly influenced the development of this field. These articles primarily focus on instructional design, assessment models, and the integration of technology in fostering higher-order thinking and process skills.

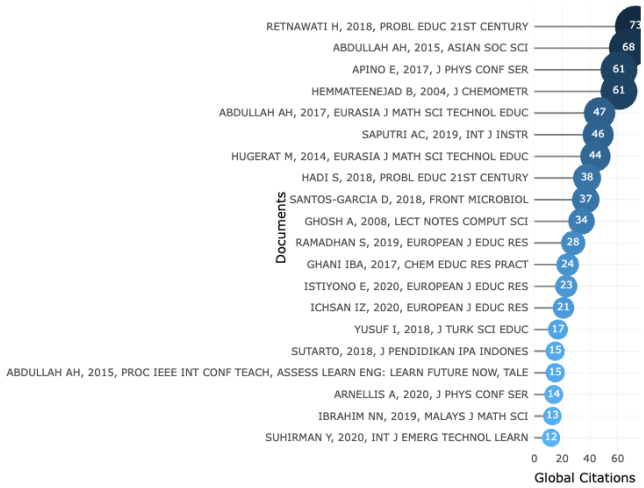

Figure 8. Top globally cited documents

(Source: Scopus/Bibliometrix export, 2023)

Keyword Frequency and Trending Topics

Keyword co-occurrence analysis reveals the dominant themes and their evolution over time. Figure 9 shows the most frequently used author keywords, where students and HOTS appeared as the most common, followed by educational computing and learning systems.

Figure 10 presents the trending topics across the time span, showing an increasing focus on HOTS integration with educational technology. The emergence of themes such as problem-based learning, e-learning, and assessment instruments reflects how the research emphasis has progressively expanded toward digital pedagogy and innovative assessment practices.

The dominance of keywords such as students, HOTS, and educational computing indicates that most studies operationalize higher-order thinking through learner-centered and technology-supported inquiry activities. This finding confirms that SPS functions as a procedural pathway through which HOTS is enacted in science learning, particularly via experimentation, data interpretation, and problem-based tasks.

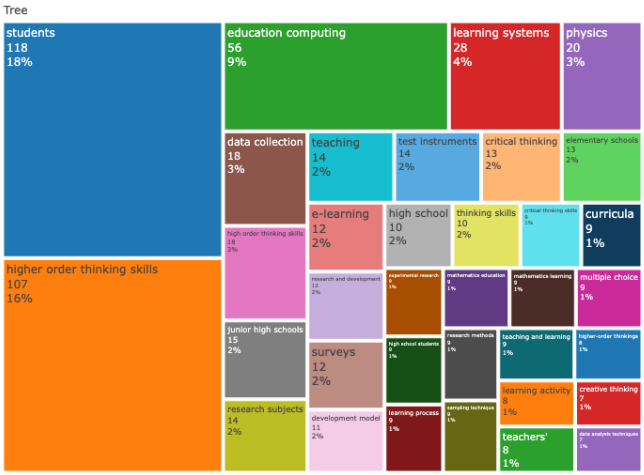

Figure 9. Most relevant author keywords

(Source: Scopus/Bibliometrix export, 2023)

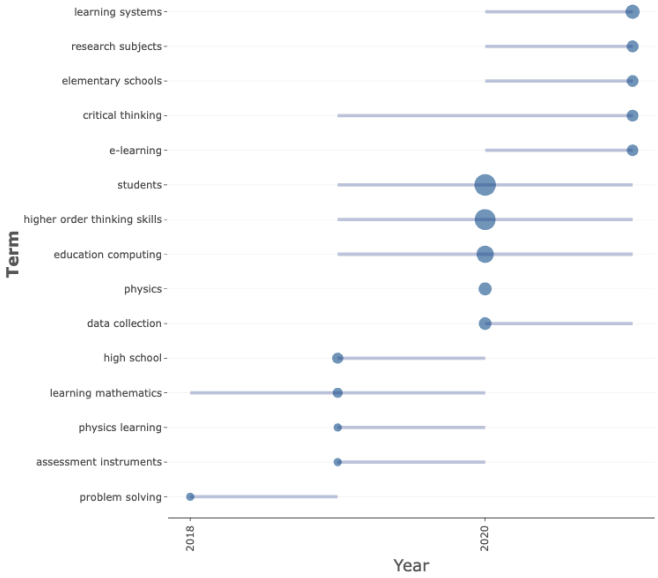

Figure 10. Trending topics

(Source: Scopus/Bibliometrix export, 2023)

Conceptual Structure Analysis

First, Network Visualization (MCA)

To understand the conceptual relationships among research themes, Multiple Correspondence Analysis (MCA) was applied to author keywords. Figure 11 shows three distinct clusters represented by different colors. The node size corresponds to the frequency of keyword occurrence, while the proximity between nodes reflects conceptual relatedness. The clusters represent interconnected research domains focusing on HOTS, teaching and learning, and learning processes.

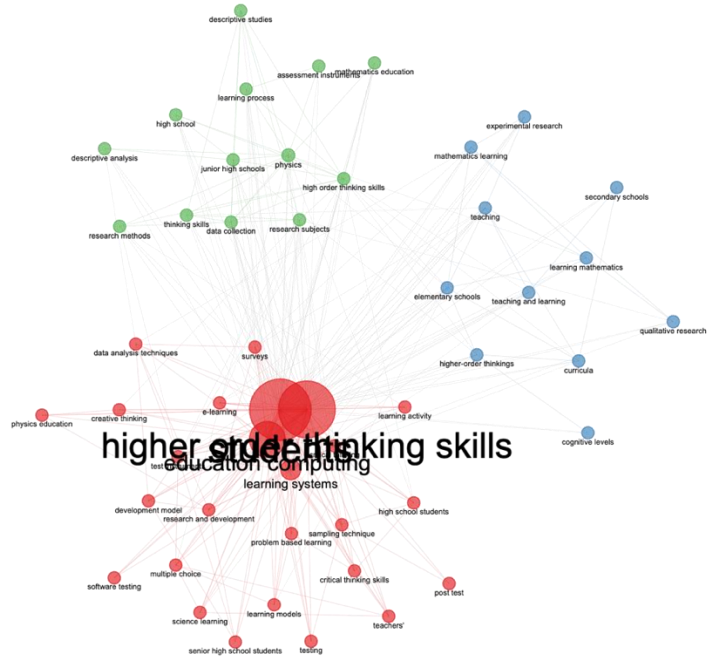

Figure 11. Conceptual network (MCA) of author keywords

(Source: Scopus/Bibliometrix export, 2023)

Second, Thematic Map

Thematic mapping was used to categorize topics based on centrality and density, identifying motor themes, basic themes, emerging/declining themes, and niche themes. Figure 12 illustrates the typology of topics within the HOTS–SPS research field, showing how certain areas have transitioned from foundational conceptual studies to more applied educational contexts.

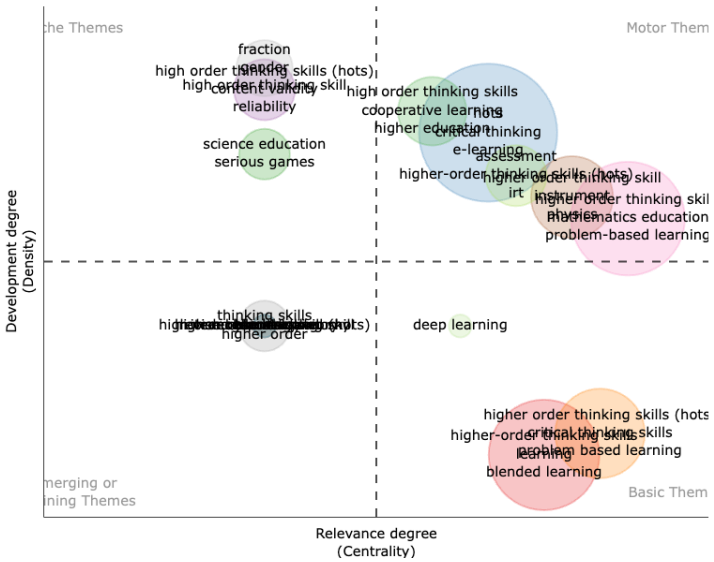

Figure 12. Thematic map

(Source: Scopus/Bibliometrix export, 2023)

Third, Citation and Collaboration Networks

Co-Author and Citation Network

Co-authorship and citation network analyses were conducted to examine author interconnections and the influence of collaborative research patterns. Figure 13 visualizes author clusters generated using the Louvain algorithm. Each color represents a distinct collaboration group, with node size indicating author productivity and edge thickness indicating the strength of co-authorship or co-citation links.

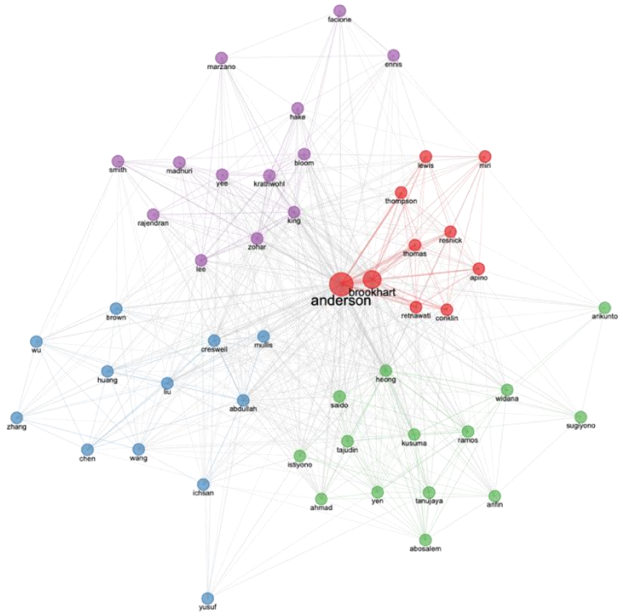

Figure 13. Co-author/citation network

(Source: Scopus/Bibliometrix export, 2023)

Country and Institutional Collaboration

Collaboration analysis was extended to examine geographical and institutional dynamics in HOTS–SPS research. Figure 14 maps scientific production by country, while Figure 15 presents institutional collaboration networks for the top 50 institutions. The results indicate that Southeast Asian countries—particularly Indonesia and Malaysia—dominate in productivity and cross-institutional collaboration. Several universities, such as Yogyakarta State University and Universiti Teknologi Malaysia, show strong linkages within the global research network.

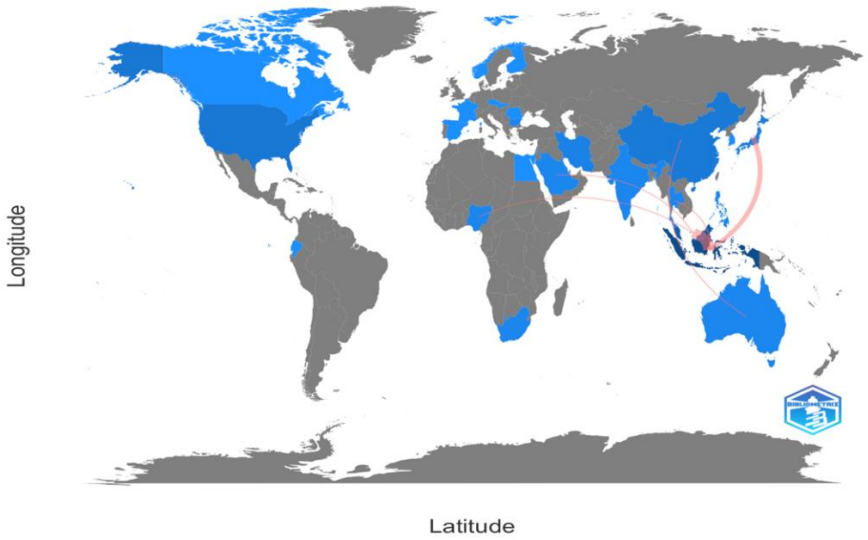

Figure 14. Country scientific production

(Source: Scopus/Bibliometrix export, 2023)

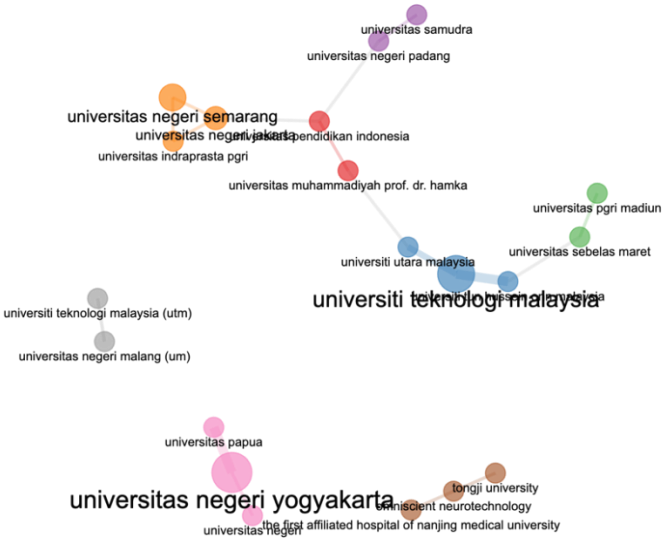

Figure 15. Institutional collaboration network

(Source: Scopus/Bibliometrix export, 2023)

Overall, the results demonstrate that the bibliometric findings are not merely descriptive outcomes but represent the culmination of a structured research process involving systematic data retrieval, screening, statistical computation, and network visualization. The depth of analysis across sources, authors, keywords, and collaboration networks provides a robust empirical foundation for understanding how HOTS and SPS research has evolved from conceptual discussions into applied, technology-supported instructional practices in science education.

Discussion

The bibliometric analysis demonstrates that research on Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) has grown steadily from 1992 to 2023, with a notable surge occurring after 2014. This peak trend coincides with the global diffusion of 21st-century skills frameworks and national curriculum reforms that emphasize critical thinking, creativity, and inquiry-based learning as essential educational outcomes (Seman et al., 2017). In the context of elementary education (MI/SD), this growth reflects increasing recognition that foundational scientific reasoning and problem-solving skills must be cultivated from early schooling through the integration of HOTS and SPS.

An examination of publication sources reveals the dominance of conference proceedings, such as the Journal of Physics: Conference Series and AIP Conference Proceedings. This pattern suggests that much of the innovation in HOTS-SPS research emerges from empirical classroom-based studies, instructional model development, and pilot-scale interventions rather than from long-term longitudinal investigations (Van Nunen et al., 2018). While conference dissemination enables rapid knowledge sharing and responsiveness to curricular change, it also indicates that the field is still consolidating its theoretical foundations and requires more high-impact journal publications to strengthen research maturity.

Keyword co-occurrence and thematic analyses further reveal that dominant themes in HOTS-SPS research include students, HOTS, educational computing, learning systems, problem-based learning, e-learning, and assessment instruments. These themes indicate a strong conceptual integration between higher-order cognitive processes and science process skills, particularly within technology-supported learning environments. This finding supports prior studies emphasizing that digital tools and inquiry-oriented activities can simultaneously enhance students' analytical reasoning and procedural scientific skills (Harta et al., 2020). The thematic evolution from conceptual discussions toward applied instructional and assessment models highlights a shift toward operationalizing HOTS through SPS-based learning experiences (Widia et al., 2025).

Geographically, the analysis identifies Indonesia and Malaysia as the most productive contributors to HOTS-SPS research (Aparicio et al., 2019). This trend aligns

with national education policies, such as the Merdeka Curriculum and STEM-oriented reforms, which explicitly promote inquiry, experimentation, and performance-based assessment in science education (Retnawati, Djidu, Kartianom, & Anazifa, 2018). Importantly, the bibliometric evidence shows that a substantial proportion of studies from these countries directly examine how HOTS is enacted through SPS, including hypothesis formulation, data interpretation, and variable manipulation. Strong international collaboration, particularly between institutions such as Yogyakarta State University and Universiti Teknologi Malaysia, further indicates that HOTS-SPS research is developing within a collaborative regional knowledge ecosystem. Such collaboration accelerates the diffusion of instructional innovations and strengthens methodological rigor through shared expertise (Apino & Retnawati, 2017; Nugroho, Wilujeng, & Pujaningsih, 2024).

From a conceptual standpoint, the growing emphasis on assessment instruments and validation processes reflects a paradigm shift from content-based testing toward performance-based and authentic assessment. This shift is consistent with the view that research frontiers evolve toward multidimensional and collaborative domains when pedagogy intersects with assessment innovation (Breschi & Catalini, 2010). The emergence of themes such as critical thinking, problem solving, and curriculum development reinforces the argument that HOTS and SPS are increasingly treated as complementary constructs (Kusumadani et al., 2023). As noted by Faradella (2024), students' difficulties in HOTS-related problem solving often stem from limited exposure to inquiry-based and process-oriented tasks, further underscoring the need for integrated instructional designs.

In relation to educational practice, the bibliometric findings provide strong pedagogical implications for elementary science education. The alignment between HOTS and SPS identified in this study corroborates earlier empirical research showing that instruction emphasizing analysis, evaluation, and creation enhances students' abilities to observe, classify, interpret data, and draw scientific conclusions Retnawati et al., 2018). Similarly, inquiry-based and problem-based learning models have been shown to effectively link hypothesis formulation, experimentation, and evidence interpretation with higher-order cognitive engagement (Nugroho, Wilujeng, Pujaningsih, et al., 2024). These findings indicate that HOTS-oriented instruction naturally supports SPS development when learning tasks are designed around authentic scientific inquiry.

From a theoretical perspective, the relationship between Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) can be understood as a reciprocal and hierarchical interaction. HOTS provides the cognitive framework that enables learners to engage meaningfully in science process skills, as analytical, evaluative, and creative thinking are required to formulate hypotheses, design investigations, interpret data, and draw evidence-based conclusions. Conversely, SPS functions as the operational mechanism through which HOTS is enacted and becomes observable in learning activities (Zhou & Qu, 2024). When students engage in processes such as observing patterns, controlling variables, analyzing experimental results, and communicating findings, they actively exercise higher-order cognitive processes. This interpretation aligns with constructivist and self-regulated learning theories, which emphasize that higher-level cognition develops through active inquiry, reflection, and problem-solving experiences (Zimmerman, 2007; Liu et al., 2008; Council et al., 2012).

The prominence of keywords related to educational computing and learning systems further highlights the role of digital environments in facilitating formative assessment and adaptive learning. Digital platforms enable real-time feedback, systematic data collection, and individualized instruction, thereby supporting the development of both cognitive reasoning and procedural scientific skills (Harta et al., 2020). This trend aligns with broader global movements toward digital transformation and AI-assisted assessment in education, preparing elementary students for the demands of the Industrial Revolution 4.0 (Nugroho et al., 2025; Yadav & Shrawankar, 2025).

Despite the increasing volume of publications, the bibliometric findings indicate that research explicitly addressing the implementation of Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) at the elementary school (MI/SD) level remains uneven. While a considerable number of studies discuss HOTS and SPS conceptually or within broader educational contexts, fewer articles provide detailed empirical evidence on how these skills are systematically embedded in classroom practices at the primary level. Most studies emphasize instructional models or assessment instruments without sufficiently documenting sustained classroom implementation, longitudinal outcomes, or institutional adoption within elementary schools. This suggests that, although HOTS and SPS are widely acknowledged in theory, their practical enactment in MI/SD contexts is still partial and fragmented.

The bibliometric distribution further reveals a gap between research production and school-level implementation. Many publications originate from higher education institutions and research centers, yet relatively few examine institutional readiness, school culture, or teacher capacity in elementary schools. This indicates that a significant number of MI/SD institutions may not yet be implementing HOTS-and SPS-oriented learning in a systematic manner. Contributing factors include limited teacher assessment literacy, curriculum constraints, an emphasis on content coverage and recall-based testing, and insufficient alignment between national assessment systems and inquiry-based learning goals. As a result, HOTS and SPS are often treated as supplementary objectives rather than as core components of elementary science instruction.

Based on these findings, this study offers several solution-oriented directions. First, HOTS and SPS should be integrated explicitly into elementary science curricula as interconnected competencies, supported by clear learning progressions and assessment indicators appropriate to students' developmental levels. Second, teacher professional development programs need to prioritize HOTS-SPS integration by focusing on inquiry-based pedagogy, performance-based assessment, and reflective instructional practices. Third, digital learning systems and formative assessment platforms identified as emerging themes in the bibliometric analysis can be leveraged to support real-time feedback, documentation of science process skills, and the evaluation of higher-order thinking in classroom settings. Finally, future research should move beyond short-term instructional trials and focus on design-based and longitudinal studies that validate HOTS–SPS integration across diverse elementary school contexts.

The implications of these findings are significant for elementary science education policy and practice. For schools, the results highlight the need to shift from fragmented implementation toward a coherent instructional framework that aligns learning objectives, teaching strategies, and assessment systems with HOTS and SPS development. For curriculum developers and policymakers, the findings emphasize the importance of embedding inquiry-based learning, authentic assessment, and teacher capacity-building within national curriculum and evaluation frameworks. At the research level, the study underscores the need for stronger theoretical consolidation and empirical validation to ensure that HOTS–SPS integration moves from policy discourse into sustainable classroom practice. Overall, this bibliometric evidence positions HOTS and

SPS not merely as aspirational skills, but as essential and actionable foundations for cultivating scientific literacy and higher-order thinking in elementary education.

Conclusion

This bibliometric study provides a comprehensive overview of the evolution of research on Higher Order Thinking Skills (HOTS) and Science Process Skills (SPS) from 1992 to 2023. Rather than merely mapping publication counts, this analysis identifies the intellectual, conceptual, and social foundations of HOTS-SPS scholarship by examining key authors, publication sources, thematic structures, and collaboration networks. The findings reveal a clear research trajectory from early conceptual discussions on critical thinking toward applied studies that integrate technology, inquiry-based learning, and assessment innovation. The marked increase in publications after 2014 reflects both global and regional educational shifts toward inquiry-driven and performance-oriented science learning.

Consistent with the bibliometric approach employed in this study, the results demonstrate that HOTS and SPS research has evolved into a structured and increasingly interconnected field, particularly within elementary science education (MI/SD). Performance analysis and thematic mapping indicate that higher-order cognitive processes such as analysis, evaluation, and creation are frequently operationalized through science process skills, including observation, hypothesis formulation, data interpretation, and scientific communication. This evidence confirms that HOTS and SPS are not independent constructs but complementary dimensions of scientific literacy, in which cognitive reasoning provides the foundation for scientific inquiry, while science process skills translate higher-order thinking into observable learning practices.

At a more specific level, the bibliometric patterns identified in this study offer important implications for educational practice. Dominant research clusters, such as inquiry learning, critical thinking, scientific reasoning, classroom assessment, and digital innovation, provide evidence-based references for aligning curriculum objectives, instructional strategies, and assessment practices in elementary science education. Teachers may draw on these insights to design inquiry-oriented learning activities that integrate core science process skills with higher-order thinking strategies, thereby fostering deeper conceptual understanding and problem-solving abilities among students.

For curriculum developers and policymakers, the findings highlight priority areas for strengthening elementary science education, including the development of authentic and digital assessment tools, inquiry-based lesson structures, and sustained professional development programs focused on HOTS-SPS integration.

In terms of research continuity, this study contributes a data-driven foundation for future investigations by clarifying dominant themes, influential contributors, and underexplored areas within the HOTS-SPS literature. While the bibliometric analysis does not directly measure instructional effectiveness, it provides a systematic map of how HOTS and SPS have been conceptualized, integrated, and operationalized across scientific publications. Future research is therefore encouraged to build upon these findings through longitudinal, experimental, or design-based studies that empirically examine the impact of HOTS–SPS integration on student learning outcomes in diverse elementary school contexts.

Overall, the novelty of this research lies in its systematic integration of large-scale bibliometric evidence with pedagogical interpretation. By linking publication trends and thematic developments to theoretical and practical considerations in science education, this study offers a coherent and evidence-informed perspective that supports the advancement of HOTS-based and SPS-oriented science instruction in primary education contexts.

Acknowledgment

The authors would like to express their sincere gratitude to the Muhammadiyah University of Magelang for providing institutional support throughout the research process. Special thanks are also extended to colleagues, academic partners, and participating schools whose valuable contributions and constructive feedback significantly enhanced the quality of this study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research was funded by the Institute for Research and Community Service (LPPM) of Muhammadiyah University of Magelang for a research grant for the Revitalization of Institutional Vision (PRVI) 2025, No. 06/Kontrak/PRVI-PA/2025.

Orcid iD

Irham Nugroho https://orcid.org/0000-0003-1729-9216

Insih Wilujeng https://orcid.org/0000-0003-1900-7985

Pujaningsih https://orcid.org/0000-0003-3794-5465

Muis Sad Iman https://orcid.org/0000-0002-4311-8901

Putri Nadya Mahesawati -

References

Agbo, F. J., Oyelere, S. S., & Suhonen, J. (2021). *Produksi ilmiah dan terobosan tematik dalam lingkungan pembelajaran cerdas: analisis bibliometrik*.

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis. *International Journal of Evaluation and Research in Education*, *11*(1), 51–60. https://doi.org/10.11591/ijere.v11i1.21647

Agustina, T., Oktavia, W., & Inderasari, E. (2020). The Implementation of Higher-Order Thinking Skills (HOTS) in Text-Based Learning at SDN Banyurip 3 Sambungmacan. *Al-Bidayah: Jurnal Pendidikan Dasar Islam*, *12*(1), 15–30.

Antonio, R. P., & Prudente, M. S. (2024). Effects of Inquiry-Based Approaches on Students' Higher-Order Thinking Skills in Science: A Meta-Analysis. *International Journal of Education in Mathematics, Science and Technology*, *12*(1), 251–281.

Aparicio, G., Iturralde, T., & Maseda, A. (2019). Conceptual structure and perspectives on entrepreneurship education research: A bibliometric review. *European Research on Management and Business Economics*, *25*(3), 105–113.

Apino, E., & Retnawati, H. (2017). Developing instructional design to improve mathematical higher order thinking skills of students. *Journal of Physics: Conference Series*, *812*(1), 12100.

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975.

Breschi, S., & Catalini, C. (2010). Tracing the links between science and technology: An exploratory analysis of scientists' and inventors' networks. *Research Policy*, *39*(1), 14–26.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, *2*(2), 141–178.

Council, N. R., Behavioral, D. of, Sciences, S., Education, B. on S., & Standards, C. on a C. F. for N. K.-12 S. E. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Darmaji, Kurniawan, D. A., Astalini, Perdana, R., Kuswanto, & Ikhlas, M. (2020). Do a science process skills affect on critical thinking in science? Differences in urban and rural. *International Journal of Evaluation and Research in Education*, *9*(4), 874–880. https://doi.org/10.11591/ijere.v9i4.20687

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296.

Eady, Michelle J. and Lockyer, L. (2013). Tools for learning: technology and teaching strategies', learning to teach in the primary school. *Queensland University of Technology, Australia*, 71–89. https://ro.uow.edu.au/asdpapers/403

Elvira, G., Sergeeva, O. V, Zheltukhina, M., Sokolova, N. L., Zakharova, V., & Drobysheva, N. N. (2025). Mobile Learning in Science Education to Improve Higher-Order Thinking Skills (HOTS) and Communication Skills: Scoping Review. *Frontiers in Communication*, *10*, 1624012.

Faradella, N. E. (2024). *Teachers'strategies and Challenges in Conducting Higher Order Thinking Skills (Hots)–Based Activities in English Language Classroom*. Universitas PGRI Semarang.

Ganguly, B., D'Souza, R., & Nunes, R. (2023). Challenges in the Teaching–Learning Process of the Newly Implemented Module on Bioethics in the Undergraduate Medical Curriculum in India. *Asian Bioethics Review*, *15*(2), 155–168. https://doi.org/10.1007/s41649-022-00225-2

González-pérez, L. I., & Ramírez-montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks: systematic review. *Sustainability (Switzerland)*, *14*(3), 1–31. https://doi.org/10.3390/su14031493

Harta, J., Rasuh, N. T., & Seriang, A. (2020). Using HOTS-Based Chemistry National Exam Questions to Map the Analytical Abilities of Senior High School Students. *Journal of Science Learning*, *3*(3), 143–148.

Hidayat, R., Nugroho, I., Zainuddin, Z., & Ingai, T. A. (2024). A systematic review of analytical thinking skills in STEM education settings. *Information and Learning Sciences*, *125*(7/8), 565–586.

Ichsan, I. Z., Sigit, D. V., Miarsyah, M., Ali, A., Arif, W. P., & Prayitno, T. A. (2019). HOTS-AEP: Higher order thinking skills from elementary to master students in environmental learning. *European Journal of Educational Research*, *8*(4), 935–942. https://doi.org/10.12973/eu-jer.8.4.935

Jeronen, E., Palmberg, I., & Yli-Panula, E. (2016). Teaching methods in biology education and sustainability education including outdoor education for promoting sustainability—A literature review. *Education Sciences*, *7*(1), 1.

Keleman, M. (2021). Assessment of Higher Order Thinking Skills Through Stem Integration Project-Based Learning for Elementary Level. *International Journal of Social Science and Human Research*, *04*(04), 835–846. https://doi.org/10.47191/ijsshr/v4-i4-40

Kriswantoro, Kartowagiran, B., & Rohaeti, E. (2021). A critical thinking assessment model integrated with science process skills on chemistry for senior high school. *European Journal of Educational Research*, *10*(1), 285–298. https://doi.org/10.12973/EU-JER.10.1.285

Kusumadani, A. I., Rahardjo, S. B., Yamtinah, S., & Prayitno, B. A. (2023). Development of High-Order Thinking Skills (HOTs) Instruments with a Socio-Scientific Problem-Based Learning Approach on the Subject of Viruses. *Eurasian Journal of Educational Research (EJER)*, *107*.

Liu, O. L., Lee, H.-S., Hofstetter, C., & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures, and evidence. *Educational Assessment*, *13*(1), 33–55.

Manurung, E. M., Purwadi, Y. S., & Sugiharto, I. B. (2022). Digital Learning Process: Challenges for Specific Creativity. *Electronic Journal of E-Learning*, *20*(2), 112–119. https://doi.org/10.34190/ejel.20.2.2107

Murtono, M. (2009). Pengembangan Model Pembelajaran Ipa Bagi Siswa Madrasah Ibtidaiyah. *Al-Bidayah: Jurnal Pendidikan Dasar Islam*, *1*(1).

Musa, M., & Meor Samsudin, W. N. A. (2021). Implementasi Kemahiran Berfikir Aras Tinggi (KBAT) Matematik: Adakah Suatu Realiti? *Sains Malaysiana*, *50*(9), 2781–2790. https://doi.org/10.17576/jsm-2021-5009-23

Napaporn, S., Maneewan, S., Thamwipat, K., & Nittayathammakul, V. (2023). The Cloud-powered Hybrid Learning Process to Enhance Digital Natives' Analytical Reading Skills. *International Journal of Advanced Computer Science and Applications*, *14*(1), 622–627. https://doi.org/10.14569/IJACSA.2023.0140168

Nugroho, I., Baihaqi, A., Iman, M. S., & Tohirin. (2021). Analysis of Science Process Skills towards Teacher Professionalism in Islamic Elementary School. *Jurnal Pendidikan Dan Pembelajaran Dasar*, *14*(1), 11–19. https://doi.org/10.18860/mad.v14i1.12022

Nugroho, I., Wilujeng, I., & Pujaningsih, P. (2024). How Elementary Science Teachers' Understand Perform Science Process Skills and HOTS. *5th Borobudur International Symposium on Humanities and Social Science 2023*, 159–165.

Nugroho, I., Wilujeng, I., & Pujaningsih, P. (2025). Digital Transformation of HOTS Assessment in Elementary School Science Learning: Technological Challenges, Human Resource Readiness, and Contribution to SDG's Achievement. *E3S Web of Conferences*, *622*, 3004. https://doi.org/10.1051/e3sconf/202562203004

Nugroho, I., Wilujeng, I., Pujaningsih, P., Iman, M. S., Witanti, W., & Arifah, A. (2024). Analysis of HOTS content in the science process skills Students' and Teachers'

Handbook of the Merdeka Curriculum. *5th Borobudur International Symposium on Humanities and Social Science 2023*, 1143–1154.

Pathoni, H., Asyhar, R., Maison, M., & Huda, N. (2022). Measuring lecturer's perception in STEM approach based contextual learning implementation. *JOTSE: Journal of Technology and Science Education*, *12*(1), 132–146.

Ragab, A., Kaid, A., & Sayed, A. K. (2024). Enhancing higher order thinking skills (hots) in education: Strategies and outcomes. *TOFEDU: The Future of Education Journal*, *3*(5), 1488–1499.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2020). Online university teaching during and after the covid-19 crisis: refocusing teacher presence and learning activity. *Postdigital Science and Education*, *2*(3), 923–945. https://doi.org/10.1007/s42438-020-00155-y

Rati, N. W., Arnyana, I. B. P., Dantes, G. R., & Dantes, N. (2023). HOTS-Oriented e-Project-Based Learning: Improving 4C Skills and Science Learning Outcome of Elementary School Students. *International Journal of Information and Education Technology*, *13*(6), 959–968. https://doi.org/10.18178/ijiet.2023.13.6.1892

Reta, I. K. (2012). Pengaruh model pembelajaran berbasis masalah terhadap keterampilan berpikir kritis ditinjau dari gaya kognitif siswa. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *2*(1).

Retnawati, H., Djidu, H., Kartianom, A., & Anazifa, R. D. (2018). Teachers' knowledge about higher-order thinking skills and its learning strategy. *Problems of Education in the 21st Century*, *76*(2), 215.

Retnawati, H., Djidu, H., Kartianom, Apino, E., & Anazifa, R. D. (2018). Teachers' knowledge about higher-order thinking skills and its learning strategy. *Problems of Education in the 21st Century*, *76*(2), 215–230. https://doi.org/10.33225/pec/18.76.215

Seman, S. C., Yusoff, W. M. W., & Embong, R. (2017). Teachers challenges in teaching and learning for higher order thinking skills (HOTS) in primary school. *International Journal of Asian Social Science*, *7*(7), 534–545.

Sholahuddin, A., Yuanita, L., Supardi, Z. A. I., & Prahani, B. K. (2020). Applying the cognitive style-based learning strategy in elementary schools to improve students' science process skills. *Journal of Turkish Science Education*, *17*(2), 289–301. https://doi.org/10.36681/tused.2020.27

Siregar, T. (2025). Implementation of Problem-Based Learning (PBL) Model to Enhance Higher-Order Thinking Skills (HOTS). *Available at SSRN 5709306*.

Susilawati, S., Supriyatno, T., Yasin, A. F., Chakim, A., & Putri, C. A. (2025). The Effect of TPACK-Based Contextual Teaching and Learning Model on Student Learning Outcomes. *Educational Process: International Journal*, *16*. https://doi.org/10.22521/edupij.2025.16.279

Van Nunen, K., Li, J., Reniers, G., & Ponnet, K. (2018). Bibliometric analysis of safety culture research. *Safety Science*, *108*, 248–258.

Widia, S., Evendi, E., & Halim, A. (2025). Voices from The Classroom: Teachersâ€™ and Studentsâ€™ Perceptions of Using SPS-Based Worksheets to Promote HOTS in Science Learning (A Needs Analysis). *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran, Dan Pembelajaran*, *11*(2), 820–828.

Windschitl, M. (2009). Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve. *Presentation given at the National Academies of Science Workshop on 21st Century Skills, Washington, DC*, *15*.

Yadav, U., & Shrawankar, U. (2025). Artificial intelligence across industries: A comprehensive review with a focus on education. *AI Applications and Strategies in Teacher Education*, 275–320.

Zhou, S., & Qu, X. (2024). The Design of Collaborative Learning Activities Supporting the Development of Higher-Order Thinking--Based on Embodied Cognition Theory. *Proceedings of the 2024 9th International Conference on Distance Education and Learning*, 407–412.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, *27*(2), 172–223.