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Repositioning Scientific Reasoning in Education after COVID-19: A Bibliometric Review

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Abstract

This study aimed to examine how scientific reasoning has been repositioned in educational research in the post-COVID era through a bibliometric review. Bibliographic data were retrieved from the Scopus database, covering journal articles published between 2021 and 2025. A total of 161 articles were analyzed using Biblioshiny and VOSviewer to identify publication trends, country contributions, collaboration patterns, and thematic structures. The results showed a growing scholarly emphasis on scientific reasoning after COVID-19, particularly in relation to student-centered pedagogies, assessment practices, higher-order thinking skills, and technology-enhanced learning environments. Keyword network analysis revealed scientific reasoning as a central research theme interconnected with inquiry-based learning, problem-based learning, critical thinking, and digital learning contexts. Overlay visualization further indicated emerging research directions involving artificial intelligence and hybrid learning environments. Overall, the findings demonstrated a clear repositioning of scientific reasoning as a foundational competency in post-COVID educational research and provided insights to inform future studies and instructional innovations.

Keywords: *scientific reasoning; post-COVID education; bibliometric analysis; VoSviewer; Biblioshiny*

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INTRODUCTION

The COVID-19 pandemic has fundamentally reshaped educational systems worldwide, accelerating shifts in pedagogical practices, learning environments, and assessment strategies. In the post-COVID era, education has increasingly moved beyond content transmission toward the development of higher-order cognitive skills that enable learners to reason with evidence, evaluate information critically, and make informed decisions in complex and uncertain situations (OECD, 2021; Schleicher, 2021). Within this context, scientific reasoning has emerged as a core competency, as it underpins learners' abilities to formulate explanations, interpret data, and engage in evidence-based problem solving across disciplinary boundaries (Fischer et al., 2022; Kind & Osborne, 2023). Consequently, scientific reasoning has gained renewed prominence in educational research following COVID-19–related disruptions, particularly in response to challenges associated with learning loss, digital learning environments, and assessment validity (Teig et al., 2023; Zhai, 2022).

The term repositioning in this study refers to the shifting role, emphasis, and integration of scientific reasoning within educational research and practice in response to post-pandemic challenges. Specifically, repositioning involves: (1) the transition of scientific reasoning from a domain-specific outcome toward a cross-cutting competency essential for navigating socio-scientific and real-world problems; (2) the increasing alignment of scientific reasoning with digital, hybrid, and technology-enhanced learning environments; and (3) its growing role as a key indicator in assessing students' readiness for complex, uncertain, and data-rich contexts. Thus, repositioning is not merely a change in terminology, but reflects a broader epistemic and pedagogical shift in how scientific reasoning is conceptualized, operationalized, and prioritized in contemporary education.

Recent educational research has explored scientific reasoning through multiple perspectives, including inquiry-based learning, problem-based learning, critical thinking framework, assessment design, and technology-enhanced learning in science and medical education (Park et al., 2022; Pedaste et al., 2021; Schwichow et al., 2021). Furthermore, emerging studies in the post-COVID context emphasize the importance of integrating scientific reasoning into technology-enhanced and digitally mediated learning environments (Darling-Hammond et al., 2023; Zhai & Chang, 2024). However, a critical examination of existing literature reveals several limitations. First, many studies remain fragmented and context-specific, focusing on particular instructional strategies or local implementations without connecting these findings to broader global research trends. Second, prior reviews tend to emphasize pedagogical interventions or assessment tools, rather than examining how scientific reasoning as a construct has evolved conceptually and strategically across the research landscape. Third, there is a lack of studies that systematically investigate the global intellectual structure, collaboration networks, and thematic evolution of scientific reasoning research, particularly in the post-COVID period.

More importantly, existing literature has not sufficiently addressed how and to what extent scientific reasoning has been repositioned as a central priority in education after COVID-19. While there is growing recognition of its importance, there remains limited empirical synthesis that captures: (a) shifts in research focus and thematic priorities, (b) emerging interdisciplinary connections (e.g., with digital learning, socio-scientific issues, and sustainability education), and (c) patterns of global research collaboration that shape the

development of this field. This gap indicates the need for a more comprehensive and systematic mapping of the research landscape to identify dominant trends, emerging directions, and underexplored areas.

To address this gap, the present study conducts a bibliometric review of Scopus-indexed publications to examine how scientific reasoning research in education has been repositioned in the post-COVID era. Bibliometric analysis has been widely recognized as a robust approach for revealing research trends, collaboration patterns, and thematic structures within rapidly expanding fields (Aria & Cuccurullo, 2022; Donthu et al., 2021). Using Biblioshiny and VOSviewer, this study analyzes publication trends, country contributions, and keyword networks to provide a comprehensive overview of post-COVID scientific reasoning research.

Accordingly, this study is guided by the following research questions:
(RQ1) How have publication trends related to scientific reasoning in education evolved in the post-COVID period?
(RQ2) Which countries and research communities have contributed most significantly to scientific reasoning research after COVID-19?
(RQ3) What dominant research themes and keyword clusters characterize scientific reasoning studies in post-COVID educational research?
(RQ4) What emerging topics indicate a repositioning of scientific reasoning within contemporary educational discourse?

METHODS

This study uses a bibliometric review design to systematically map the research landscape of scientific reasoning in education in the post-COVID era. Bibliometric analysis allows for quantitative and visual exploration of publication patterns, collaboration networks, and thematic structures within a large body of scholarly literature. This approach is well-suited to identifying research trends and intellectual structures in the rapidly evolving field of educational research. The steps involved are depicted in Figure 1.

Figure 1. Bibliometric Research Stages

Data Source and Search Strategy

Bibliographic data were retrieved from the Scopus database, selected for its comprehensive coverage of high-quality, peer-reviewed journals in education and related disciplines. The selected year range was 2021 to 2025, the post-COVID-19 years. Only journal articles published in the post-COVID period were included to ensure topical relevance. To maintain data quality, search results were filtered by document type (articles only) and language (English). The final dataset was exported in BibTeX and CSV formats, making it compatible with bibliometric analysis tools.

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Data Screening and Preparation

Before analysis, the dataset underwent a filtering and cleaning process. An initial search of the Scopus database was conducted using the keyword "scientific reasoning skills," yielding 1,368 articles. The data was then filtered, including the years 2021 to 2025, the post-COVID-19 period, yielding 591 articles. Further filtering was performed, including the document type "article," the selection of relevant keywords, and the selection of English-language articles. The final search results, which were then used, totaled 161 articles.

Bibliometric Analysis Tools

Two complementary tools were used: Biblioshiny (an R package called Bibliometrix), which was used to conduct descriptive bibliometric analyses, including annual publication trends, most productive countries, international collaboration patterns, and citation analysis. VoSviewer version 1.6.19 was used to generate network visualizations, specifically keyword co-occurrence maps and overlay visualizations. These visualizations allow for the identification of dominant research themes, thematic clusters, and emerging topics in scientific reasoning research. The combined use of Biblioshiny and VoSviewer allows for quantitative synthesis and visual interpretation of bibliometric data.

Data Analysis Procedures

The analysis was conducted in four main stages. First, publication trends were examined to identify growth patterns in scientific reasoning research during the post-COVID period. Second, country-level contributions and collaboration patterns were analyzed to uncover global research participation. Third, keyword co-occurrence networks were mapped to reveal dominant research themes and their interconnections. Finally, overlay visualizations were applied to detect emerging topics and temporal shifts in research focus, providing evidence for the repositioning of scientific reasoning in contemporary educational research.

RESULTS AND DISCUSSION

Main Information

The dataset in Table 1 covers publications from 2021–2025, with a total of 161 documents from 100 sources (journals, books, etc.). Bibliometrically, the dataset is quite large because the number of sources (100) is relatively large compared to the number of documents (161), indicating that the research topic is spread across many publication channels (not concentrated in just a few journals).

Table 1. Data Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2021:2025
Sources (Journals, Books, etc)	100
Documents	161
Annual Growth Rate %	-32.24
Document Average Age	2.76
Average citations per doc	5.683
References	1419
DOCUMENT CONTENTS	

Keywords Plus (ID)	508
Author's Keywords (DE)	526
AUTHORS	
Authors	722
Authors of single-authored docs	0
AUTHORS COLLABORATION	
Single-authored docs	0
Co-Authors per Doc	7.7
International co-authorships %	26.71
DOCUMENT TYPES	
article	161

The Annual Growth Rate value of -32.24% indicates that the publication growth rate in this dataset is trending downward (in aggregate, within the range calculated by Biblioshiny). However, this decline should be interpreted in conjunction with the annual production graph (section 2), as annual fluctuations may indicate a "peak" year or a "temporary decline" year (e.g., due to indexing issues, changes in search keywords, or incomplete indexing of the last year). The average document age of 2.76 years indicates that the corpus is relatively recent (predominantly recent publications), which typically results in citation patterns that are not as high as those of more mature topics. This is consistent with the average citations per document of 5,683, which can be categorized as moderate for a relatively young dataset. Furthermore, there are 1,419 references cited by 161 articles, indicating a high citation density and a relatively rich theoretical/methodological base in this field. In terms of document content, the number of Keywords Plus = 508 and Author's Keywords = 526 illustrates the diversity of terminology used by the author, while also indicating that keyword co-occurrence mapping (VOSviewer) will form several different theme clusters.

Beyond descriptive statistics, the dispersion of 161 documents across 100 sources suggests that scientific reasoning research remains intellectually fragmented rather than consolidated within a core set of journals. This fragmentation may reflect the interdisciplinary nature of the field, where scientific reasoning is studied across science education, medical education, psychology, and educational technology. Similar patterns have been identified in emerging educational constructs, where conceptual diffusion across disciplines precedes theoretical consolidation (Donthu et al., 2021). Furthermore, the relatively high number of co-authors per document (7.7) indicates that scientific reasoning research is increasingly conducted through collaborative and interdisciplinary teams, likely driven by the complexity of post-COVID educational challenges that require expertise in pedagogy, technology, and assessment. This aligns with recent studies highlighting the growing importance of interdisciplinary collaboration in addressing learning loss and digital transformation in education (Teig et al., 2023; Zhai, 2022).

Publication Trends in Post-COVID Scientific Reasoning Research

The annual article production shows a fluctuating pattern, as shown in Figure 2. The gradual increase from 2021 to 2023 indicates a consolidation phase/the topic is starting to gain

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ground within the research community. The decline in 2024, followed by a surge in 2025, indicates a sharp acceleration in research interest in the most recent period in the dataset.

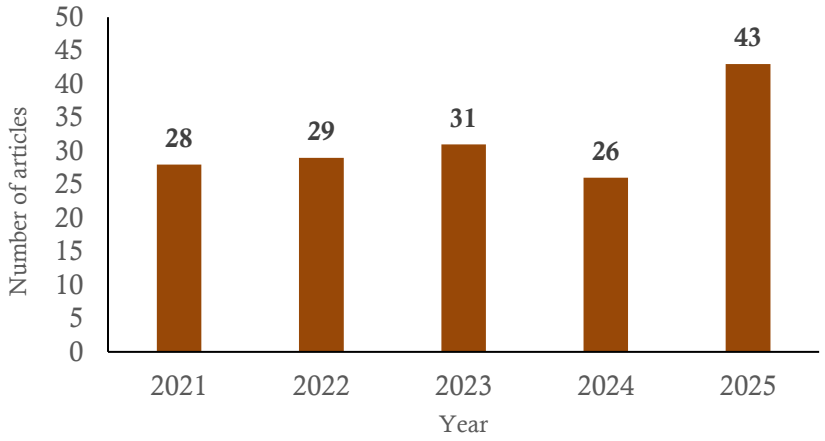

Figure 2. Publication Trend about Scientific Reasoning Skills 2021-2025

The analysis of annual scientific production demonstrates a noticeable growth in publications addressing scientific reasoning in education during the post-COVID period. This trend reflects a growing scholarly recognition of scientific reasoning as a critical educational competency following the learning disruptions caused by COVID-19. Previous studies have highlighted that post-COVID educational reforms increasingly prioritize higher-order cognitive skills to address learning loss, conceptual understanding gaps, and students' reduced capacity for evidence-based reasoning (OECD, 2021; Schleicher, 2021; Darling-Hammond et al., 2023).

The observed increase in scientific reasoning research aligns with recent findings that emphasize the importance of reasoning-oriented learning outcomes in preparing students to navigate uncertainty, misinformation, and complex socio-scientific challenges (Fischer et al., 2022; Kind & Osborne, 2023). From a bibliometric perspective, the upward trend in publications suggests that scientific reasoning has been repositioned from a supporting skill to a central research focus in post-COVID educational discourse. These findings directly address RQ1, confirming that scholarly attention to scientific reasoning has intensified in response to post-pandemic educational demands.

The observed fluctuations should be interpreted as reflecting structural shifts in research priorities rather than simple variations in publication output. The initial increase (2021–2023) likely represents the immediate response of the research community to pandemic-related disruptions, where scientific reasoning was revisited as a key competency to address learning loss and misinformation (Darling-Hammond et al., 2023). The decline observed in 2024 may indicate a transition phase, during which early exploratory studies evolved into more specialized research themes, including technology-enhanced reasoning and AI-supported assessment. This pattern is consistent with the lifecycle of emerging research areas, where rapid initial growth is followed by consolidation and thematic refinement (Donthu et al., 2021). The subsequent increase in 2025 suggests that scientific reasoning is no longer treated as a temporary response to the pandemic but has been repositioned as a sustained research priority within post-COVID educational discourse.

Global Contributions and Research Collaboration

The country-level analysis (Figure 3) reveals that scientific reasoning research in the post-COVID era is globally distributed, with contributions originating from both developed and developing countries. Such diversity indicates that the challenges of fostering scientific reasoning are shared across educational systems worldwide. Previous studies have emphasized that post-COVID educational issues such as digital inequality, assessment validity, and instructional adaptation have encouraged broader international collaboration (Teig et al., 2023; Zhai, 2022).

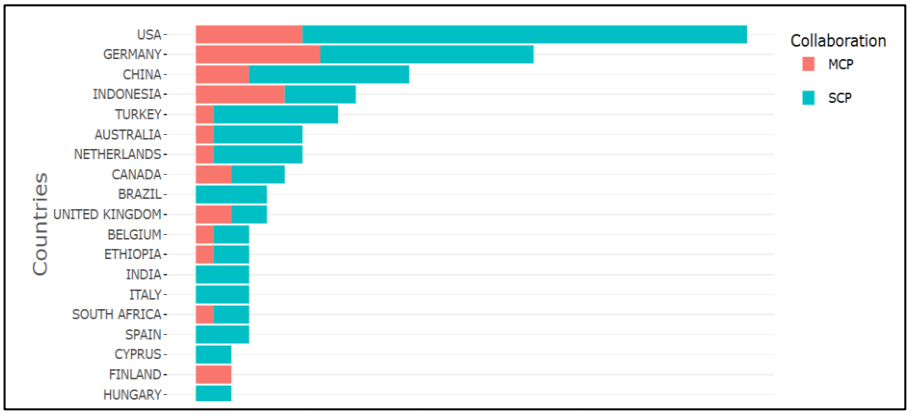

Figure 3. Most Relevant Countries

Figure 3 shows the most productive countries, with the split between single-country publications (SCP) and multiple-country publications (MCP) generally representing domestic publications versus cross-country collaborations. The countries that appear dominant include the USA, Germany, China, Indonesia, Turkey, Australia, the Netherlands, Canada, Brazil, the United Kingdom, and several others (e.g., Belgium, India, Italy, South Africa, Spain, Finland, Hungary, etc.).

The discrepancy between publication volume and citation impact among countries suggests that influence in scientific research is not solely determined by productivity. Countries with fewer publications but higher citation rates often contribute theoretically or methodologically influential studies, particularly in assessment and instructional design (Schwichow et al., 2021). These findings address RQ2, highlighting that post-COVID scientific reasoning research is shaped by both prolific research communities and high-impact contributors within a global collaboration network.

The global distribution of publications reflects not only shared educational challenges but also asymmetries in research capacity and knowledge production. Countries such as the USA, China, and Germany dominate in volume due to stronger research infrastructure, while other countries may demonstrate higher citation impact by contributing more conceptually or methodologically influential studies. This imbalance suggests that scientific reasoning research is shaped by a center–periphery dynamic, where knowledge production is concentrated but knowledge influence is more distributed. Similar patterns have been reported in global science education research, where collaboration networks play a critical role in amplifying research visibility and impact (Zhai & Chang, 2024). Moreover, the relatively moderate percentage of international co-authorship (26.71%) indicates that while collaboration exists, there is still

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significant potential to expand cross-national research partnerships, particularly in addressing context-specific challenges such as digital inequality and culturally responsive pedagogy.

Thematic Structure of Scientific Reasoning Research

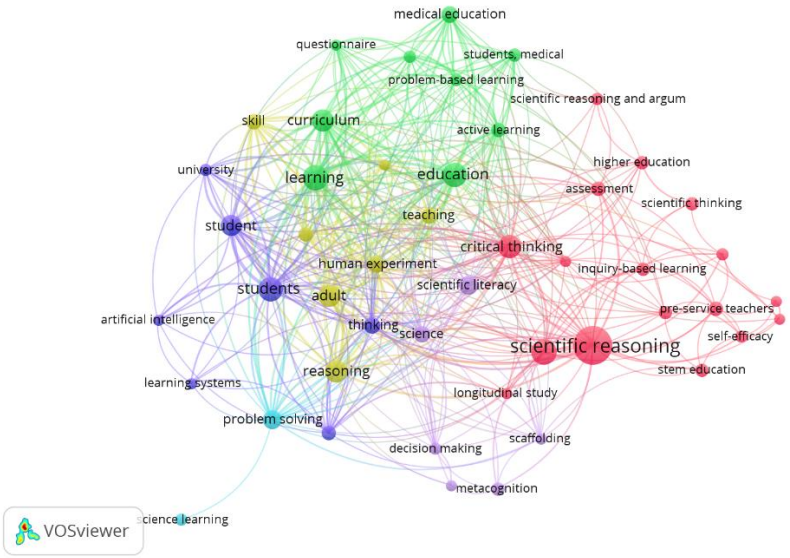

Figure 4. Network of Keyword

The node size in Figure 4 represents the frequency of occurrence, while the proximity and thickness of the lines indicate the strength of the co-occurrence (link strength) between terms. The most central and largest node is "scientific reasoning," which is strongly connected to critical thinking, inquiry-based learning, assessment, higher education, and pre-service teachers. This indicates that your corpus focuses heavily on scientific reasoning as a target skill, as well as its relationship to learning strategies (inquiry-based learning/PBL), contexts (higher education/teacher education), and assessment.

A cluster with nodes such as "education," "learning," "teaching," "active learning," "problem-based learning," and links to medical education and students and medical professionals is visible. This means that some of the literature in your dataset comes from the health/medical education field, which frequently uses PBL and active learning as approaches to training reasoning. Keywords such as "students," "student," "adult," and "relationship to university" indicate that the population studied is primarily students (especially in higher education). You can use this to identify gaps: for example, if your manuscript focuses on prospective science teachers, you can demonstrate your contribution to the teacher education subpopulation.

Nodes "thinking," "reasoning," "problem-solving," "decision-making," "metacognition," and "scientific literacy" appear. This illustrates that scientific reasoning is not viewed as a single construct, but rather as connected to cognitive processes and scientific literacy. Nodes such as "artificial intelligence" and "learning systems" appear in the network, indicating a research intersection toward utilizing AI technology for reasoning assessment learning. Although not as large as the core nodes, their emergence is important to discuss as a growing research direction in the recent period.

The keyword co-occurrence network generated using VoSviewer positions scientific reasoning as the most central and interconnected concept, confirming its role as the intellectual core of the research field. This finding is consistent with prior studies that conceptualize

scientific reasoning as a multidimensional construct closely related to inquiry, argumentation, and evidence-based thinking (Fischer et al., 2022; Zimmerman, 2021). Several dominant thematic clusters emerge from the analysis. One cluster links scientific reasoning with inquiry-based learning, problem-based learning, and active learning, reinforcing the long-standing view that reasoning skills are best developed through student-centered pedagogical approaches (Pedaste et al., 2021; Schwichow et al., 2021). Another cluster associates scientific reasoning with assessment and evaluation, reflecting a growing concern for measuring reasoning skills accurately in post-COVID learning environments, particularly in online and hybrid settings (Nehm et al., 2021).

Additionally, a cluster connecting scientific reasoning with critical thinking, problem solving, and decision making underscores its positioning as a core higher-order cognitive skill. This thematic structure addresses RQ3, demonstrating that post-COVID scientific reasoning research integrates pedagogy, cognition, and assessment rather than treating reasoning as an isolated learning outcome. This thematic structure also indicates a conceptual shift in the positioning of scientific reasoning. The strong connections between scientific reasoning and constructs such as critical thinking, metacognition, and problem solving suggest that it is increasingly viewed as part of a broader higher-order cognitive system. Such integration reflects the demands of post-COVID education, where learners are required not only to understand scientific concepts but also to evaluate information, make decisions, and respond to complex socio-scientific challenges. Additionally, the presence of medical education within the network highlights the cross-disciplinary transfer of pedagogical approaches, particularly problem-based learning, which has long been used to develop reasoning in clinical contexts.

Emerging Topics and the Repositioning of Scientific Reasoning

Overlay visualization analysis reveals a temporal shift in research focus, with more recent studies emphasizing technology-enhanced learning, digital platforms, and artificial intelligence. This shift reflects broader post-COVID transformations in education, where digital tools have become integral to instructional delivery and assessment practices (Zhai & Chang, 2024). Recent studies suggest that technology-supported environments offer new opportunities for fostering and assessing scientific reasoning, such as through learning analytics, intelligent tutoring systems, and AI-assisted feedback (Chen et al., 2022; Holmes et al., 2023). Consequently, scientific reasoning is no longer framed solely as an outcome of traditional classroom instruction but as a competency that must be cultivated within digitally mediated and data-rich learning ecosystems. These findings directly address RQ4, providing empirical evidence that scientific reasoning has been repositioned to align with post-COVID educational realities.

The emergence of artificial intelligence and digital learning systems is particularly significant, as it reflects a shift from viewing scientific reasoning as an internal cognitive process toward understanding it as a data-informed and technologically mediated competency. This transformation suggests that scientific reasoning is increasingly shaped by interactions with digital tools, learning analytics, and adaptive systems, which redefine how reasoning is developed and assessed (Holmes et al., 2023). As a result, the repositioning of scientific reasoning extends beyond curriculum design to encompass new forms of knowledge construction within digitally mediated environments.

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Conceptual Implications for Post-COVID Education

Taken together, the bibliometric findings indicate a clear conceptual repositioning of scientific reasoning in post-COVID educational research. The field has shifted from an emphasis on instructional strategies alone toward a more integrated perspective that combines pedagogy, assessment, cognitive processes, and educational technology. This shift aligns with contemporary educational frameworks that emphasize resilience, adaptability, and evidence-based thinking as essential competencies for post-pandemic learners (Baltador et al., 2024; Darling-Hammond et al., 2023; OECD, 2021). By mapping publication trends, global contributions, and thematic evolution, this study provides a comprehensive overview of how scientific reasoning research has responded to post-COVID challenges. These findings offer a foundation for future research aimed at designing robust learning environments and assessment frameworks that support the development of scientific reasoning in diverse educational contexts.

Based on these findings, future research is encouraged to move beyond descriptive mapping and focus on the design and evaluation of learning approaches that explicitly foster scientific reasoning. In particular, research integrating Socio-Scientific Issues (SSI) can examine how real-world, controversial problems support learners' ability to reason with evidence and make informed decisions. Additionally, the integration of Design Thinking offers opportunities to explore scientific reasoning through iterative problem framing, solution development, and reflective evaluation. Furthermore, Project-Based Learning (PjBL) provides a promising framework for investigating how sustained, collaborative projects can promote scientific reasoning alongside communication and problem-solving skills. Future studies may also consider hybrid or integrated models combining SSI, Design Thinking, and PjBL to develop and assess scientific reasoning in diverse post-COVID educational contexts. Importantly, this study contributes not only by mapping the research landscape but also by providing a theory-informed interpretation of how scientific reasoning is being repositioned within post-pandemic education. This extends previous research that has primarily focused on instructional strategies without examining the broader conceptual evolution of scientific reasoning.

CONCLUSION

This bibliometric review shows that scientific reasoning has been repositioned as a core focus in educational research in the post-COVID era. The findings indicate a clear shift toward emphasizing scientific reasoning in relation to student-centered pedagogies, assessment practices, higher-order thinking skills, and technology-enhanced learning environments. Rather than being treated as a supplementary learning outcome, scientific reasoning increasingly functions as a foundational competency aligned with contemporary educational demands. From a theoretical perspective, these findings contribute to the evolving understanding of scientific reasoning as an integrated and multidimensional construct that extends beyond disciplinary boundaries. The strong connections between scientific reasoning, critical thinking, and digital learning environments suggest a paradigm shift in which reasoning is positioned as part of a broader cognitive and epistemic framework required for navigating complex, uncertain, and data-rich contexts in post-pandemic education.

From a practical perspective, the results highlight the importance of explicitly integrating scientific reasoning into instructional design, assessment strategies, and technology-supported learning environments. Approaches such as inquiry-based learning, project-based learning, and the integration of Socio-Scientific Issues (SSI) provide meaningful contexts for developing students' reasoning abilities. In addition, the emergence of digital platforms and artificial

intelligence indicates the need for adaptive and data-informed approaches to support the teaching and assessment of scientific reasoning in diverse educational settings. This study provides a systematic overview of research trends and thematic developments that can inform future research and educational practices aimed at strengthening scientific reasoning in post-COVID education. These findings also offer a strategic foundation for aligning scientific reasoning with the evolving demands of Education 4.0 and Society 5.0.

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