

Research Trends and Hotspots in the Integrated Science Curriculum (1947–2024): A CiteSpace Analysis

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Abstract

The integrated science curriculum has become a central theme in global education reforms, yet its research development remains fragmented. This study employs CiteSpace 6.3 to conduct a scientometric analysis of 350 publications retrieved from Web of Science, Scopus Abstract and Citation Database, and China National Knowledge Infrastructure (1947–2024). Publication trends reveal three phases: marginal development (1947–1995), gradual growth (1996–2005), and rapid expansion linked to STEM initiatives and the NGSS (2005–2019), followed by a decline after 2020 due to the COVID-19 pandemic. The United States, China, and Canada dominate contributions, with the Texas A&M University System and the Purdue University System identified as leading institutions. Author and institutional networks highlight active but regionally clustered collaborations. Keyword co-occurrence indicates that curriculum design, student learning, and teaching practices remain consistent research themes. Keyword clustering demonstrates interdisciplinary expansion into sustainability, computer science, and nanoeducation, reflecting broader societal and technological agendas. Keyword burst detection identifies recent surges in “science curriculum” and “students” (2021–2024), signaling growing emphasis on curriculum innovation and learner engagement. These findings provide a systematic visualization of integrated science curriculum research hotspots, offering valuable insights for both future scholarship and educational policy.

Keywords: Integrated Science Curriculum, Scientometric Analysis, CiteSpace, Research Trends and Hotspots, Interdisciplinarity

Introduction

In the 21st century, scientific literacy has been recognised as a core competency underpinning innovation, sustainability, and informed citizenship (Miller, 1983; Kennedy & Cherry, 2023). Governments and international organisations increasingly emphasise interdisciplinary and practice-oriented curricula to prepare students for complex real-world challenges. In this

context, the integrated science curriculum (ISC) has emerged as a prominent reform initiative, seeking to overcome the limitations of fragmented subject-based instruction (Åström, 2008). Instead of teaching physics, chemistry, biology, and geography separately, ISC integrates concepts and methods across disciplines, aiming to cultivate holistic understanding, inquiry capacity, and transferable problem-solving skills (Wall & Leckie, 2017).

Globally, ISC aligns with broader STEM education reforms and frameworks such as the Next Generation Science Standards (NGSS) in the United States, which integrate disciplinary core ideas, scientific practices, and crosscutting concepts (National Research Council, 2012). In China, the Compulsory Education Science Curriculum Standards (2022 Edition) explicitly advocate interdisciplinary learning pathways across four literacy domains: scientific understanding, scientific thinking, scientific inquiry and practice, and scientific attitudes and responsibility (Ministry of Education of China, 2022).

Despite policy support, ISC research has encountered persistent challenges. Teachers trained in single disciplines often find it difficult to adapt to interdisciplinary pedagogy. Curriculum materials have sometimes lacked coherence, leading to fragmented implementation (Fei, 2012). Moreover, significant disparities exist across contexts, particularly between urban and rural schools, in teacher quality, facilities, and resource provision (Miao et al., 2024). More fundamentally, academic scholarship on ISC has been criticised for being fragmented and uneven, with insufficient comparative and evaluative work (Zhu, 2017).

As the importance of the ISC continues to grow, the challenges and trajectories it faces are also constantly evolving. The field has witnessed shifts in policy priorities, pedagogical approaches, and implementation contexts, reflecting both global trends and localised constraints. These dynamics highlight the necessity of systematically tracing the developmental pathways of ISC, identifying research hotspots, and uncovering emerging trends. By mapping its patterns of growth and change, scholars and practitioners can gain a clearer understanding of how ISC has been conceptualised, implemented, and debated across different stages and regions. Such a comprehensive overview not only advances theoretical understanding but also informs practical strategies for curriculum design, teacher professional development, and equitable policy formulation, thereby ensuring that ISC fulfils its intended role in fostering scientific literacy and preparing students for future societal demands.

Bibliometric and scientometric methods—especially the use of visualization software such as CiteSpace (C. Chen, 2017)—provide powerful tools to map and synthesise knowledge development across decades. CiteSpace supports the identification of research fronts, collaboration structures, and thematic evolution by integrating co-citation and co-authorship network analysis with cluster labeling and burst detection algorithms (C. Chen, 2006). In education-related domains, CiteSpace has been widely used to map STEM education and adjacent fields: for instance, mapping global STEM education trends and research frontiers, including teacher professional development and 21st-century skills (Yang et al., 2023); examining K–12 engineering education research to reveal hotspots and developmental trajectories (Jin et al., 2024); and visualizing classroom engagement dynamics through literature mapping (Zhang et al., 2025). Despite these applications, a consolidated

scientometric visualization focused specifically on ISC literature remains limited, underlining the need for a domain-specific mapping of ISC research structures and emerging themes.

This study addresses this gap by conducting a CiteSpace-based scientometric analysis of ISC publications from 1947 to 2024. It aims to:

- (1) Identify publication trends and key developmental phases;
- (2) Map author, institutional, and country collaboration networks;
- (3) Analyse research hotspots through keyword co-occurrence and clustering;
- (4) Detect emerging themes via keyword burst analysis.

By doing so, the study contributes a comprehensive picture of ISC scholarship over seven decades, offering insights for advancing integrated science education theory, practice, and policy.

Methods

This study employed a scientometric approach to systematically analyse the research landscape of the ISC. The bibliographic data were retrieved from three major databases: Web of Science (WoS), Scopus Abstract and Citation Database (Scopus), and China National Knowledge Infrastructure (CNKI). The search was conducted in early July 2024, using the following keywords or subject terms: “integrated science,” “integrated science curriculum,” “comprehensive science curriculum,” “lower secondary science education,” and “lower secondary integrated science curriculum.” After removing duplicate records, incomplete entries, non-academic publications, and studies irrelevant to the research theme, a total of 350 valid publications were obtained: 143 from WoS, 79 from Scopus, and 128 from CNKI.

The scientometric analysis was carried out using CiteSpace 6.3. It achieves this through algorithms for co-citation, co-authorship, and keyword co-occurrence, as well as clustering and burst detection techniques. In this study, the CiteSpace settings were as follows: the timespan was defined as 1947–2024; the time slice was set to one year; the selection criteria employed the g-index ($k = 25$); and the pruning method applied the Pathfinder algorithm, while all other thresholds were kept at system defaults. These configurations follow established practices in scientometric studies in educational research (C. Chen, 2016).

Based on these data and parameters, the analysis proceeded across multiple dimensions. Specifically, annual publication trends were examined to trace the historical trajectory of ISC research; author collaboration networks were analysed to identify influential scholars and collaborative groups; institutional and national networks were mapped to determine the organisational and geographical distribution of scholarship; and keyword co-occurrence, clustering, and burst detection analyses were conducted to uncover core themes, thematic structures, and emerging trends. Together, these procedures provided a multidimensional and systematic representation of ISC research development over the past seven decades.

Findings and Discussion

Publication Trends

The annual distribution of publications demonstrates that ISC research has undergone multiple developmental phases since 1947, as shown in Figure 1. From 1947 through the early 1990s, research output remained marginal, with fewer than five articles per year, indicating

limited recognition of integrated science as a research domain. Between the mid-1990s and 2005, the output grew modestly to 5–10 articles per year, suggesting gradual acceptance of interdisciplinary perspectives in curriculum design (Åström, 2008). A significant surge occurred between 2005 and 2010, with publication output rising to approximately 15 articles annually, reflecting the growing emphasis on educational reforms and cross-disciplinary integration worldwide. From 2010 to 2020, output reached a peak of nearly 30 papers annually, coinciding with the global promotion of STEM education and policies such as the NGSS in the United States (National Research Council, 2012). After 2020, however, publication numbers declined sharply, likely due to the COVID-19 pandemic, which disrupted classroom-based research and delayed empirical curriculum studies (Daniel, 2020; García-Peñalvo, 2021). These patterns show that ISC scholarship is strongly shaped by both global reform agendas and external societal disruptions.

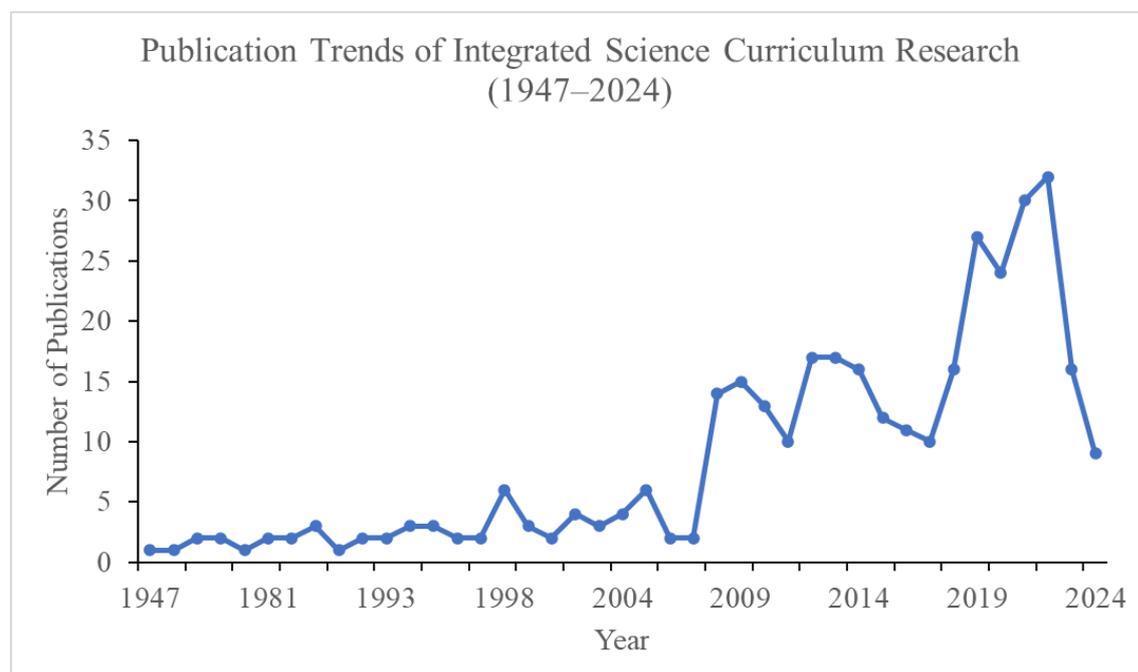


Figure 1. Annual Publication Trends in ISC Research (1947–2024)

Author Collaboration

The author collaboration network highlights several influential scholars in ISC research (see Figure 2 and Table 1). Larger nodes such as Rochintaniawati, D. and Froyd, J. E. indicate strong academic impact and extensive collaborations, while other notable contributors include Kaniawati, I. and Meyer, J. The network structure reveals multiple relatively independent sub-groups, each centred around key authors. Node colours show that most active scholars have emerged in recent years, confirming ISC as a growing research hotspot. The presence of tightly connected clusters also suggests that core research teams play a central role in advancing the field.



Figure 2. Author Collaboration Network in ISC Research (1947–2024)

Table 1

Top 10 Most Productive Authors in ISC Research (1947–2024)

Count	Author
4	Froyd, Jeffrey e
3	Kander, Ronald g
3	Rochintaniawati, D
2	Al-mutawah, Masooma
2	Alghazo, Yazan
2	Booi, K
2	Brady, Colleen
2	Chen, Lin Ching
2	Eisenbarth, Sophie
2	Erasmus, Marisa

Institutional Collaboration

The institutional collaboration network illustrates the major organisations contributing to ISC research, as shown in Figure 3 and Table2. Prominent nodes include the Texas A&M University System and Texas A&M University at College Station, both central to the field with frequent internal collaboration. Purdue University and the Purdue University System also play influential roles, alongside the State University System of Florida and the University of Florida. Other active contributors include Florida Atlantic University and the University of North Carolina. The network structure reveals several sub-groups centred on leading U.S. institutions, reflecting both their productivity and collaborative reach. The density of connections indicates an increasing trend toward cross-institutional cooperation, while the prevalence of recent activity (highlighted in red and orange nodes) confirms ISC as a growing research hotspot.



Figure 3. Institutional Collaboration Network in ISC Research (1947–2024)

Table 2

Top 10 Most Productive Institutions in ISC Research (1947–2024)

Count	University
7	State University System of Florida
5	Nanyang Technological University
4	Purdue University
4	National Institute of Education (NIE) Singapore
4	Texas A&M University College Station
4	Purdue University System
4	Texas A&M University System
3	Michigan State University
3	Weizmann Institute of Science
3	University of North Carolina

National Collaboration

The national collaboration network demonstrates the geographic distribution of ISC research and international partnerships (see Figure 4 and Table 3). The United States occupies the central position with the largest node and the most connections, indicating its leadership and extensive collaboration in the field. China also holds a prominent role, showing strong research activity and active partnerships with countries such as the United States and Canada. Canada itself appears as another significant contributor. Other countries, including South Korea, Turkey, Australia, South Africa, and England, also participate actively, reflecting the global scope of ISC scholarship. The dominance of orange and red nodes suggests that many of these collaborations have intensified in recent years.

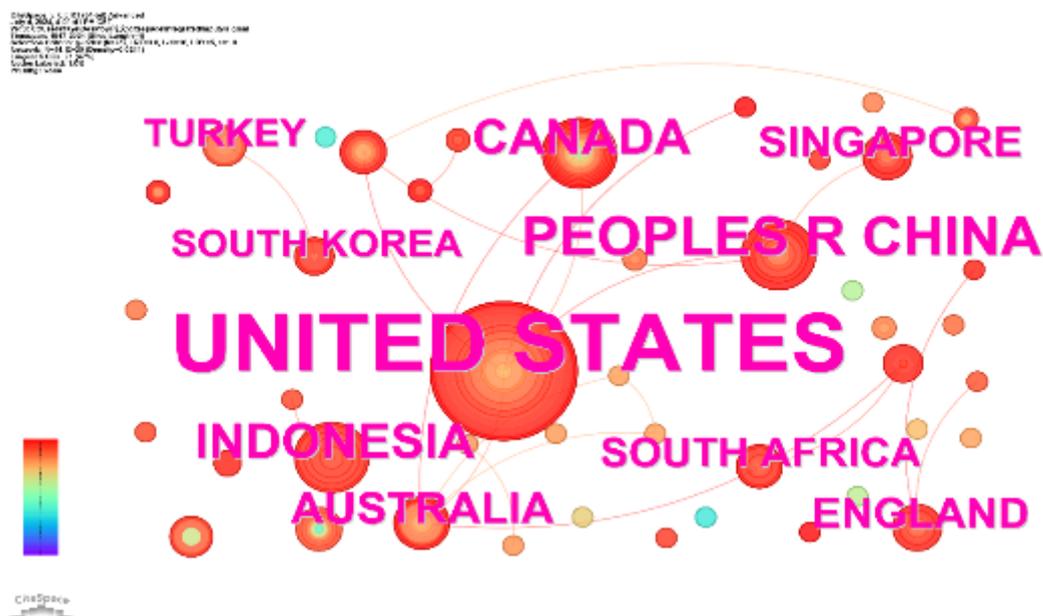


Figure 4. National Collaboration Network in ISC Research (1947–2024)

Table 3

Top 10 Most Productive Countries in ISC Research (1947–2024)

Count	Centrality	Countries
89	0.08	UNITED STATES
17	0.02	PEOPLES R CHINA
12	0	CANADA
12	0	INDONESIA
9	0.07	AUSTRALIA
8	0	ENGLAND
8	0	SINGAPORE
7	0	SOUTH AFRICA
6	0	GERMANY
6	0	SOUTH KOREA

Keyword Co-occurrence Analysis

As shown in Figure 5 and Table 4, the keyword co-occurrence network illustrates the central research concepts in ISC. High-frequency terms such as curriculum, education, students, engineering education, and curriculum development highlight two major emphases: curriculum design and reform on the one hand, and student learning, engagement, and scientific literacy on the other.

Additional terms, including medical education, design, knowledge, and teachers, further indicate the field's orientation toward pedagogical strategies, interdisciplinary integration, and the role of teacher professional capacity. The prominence of engineering and medical education reflects the growing alignment of ISC with STEM and applied fields, while the frequent appearance of students underscores the dominance of learner-centred approaches in recent years. Overall, the co-occurrence results confirm that ISC research is anchored in

curriculum development and student-centred teaching, while also expanding into interdisciplinary domains such as sustainability, engineering, and health sciences.

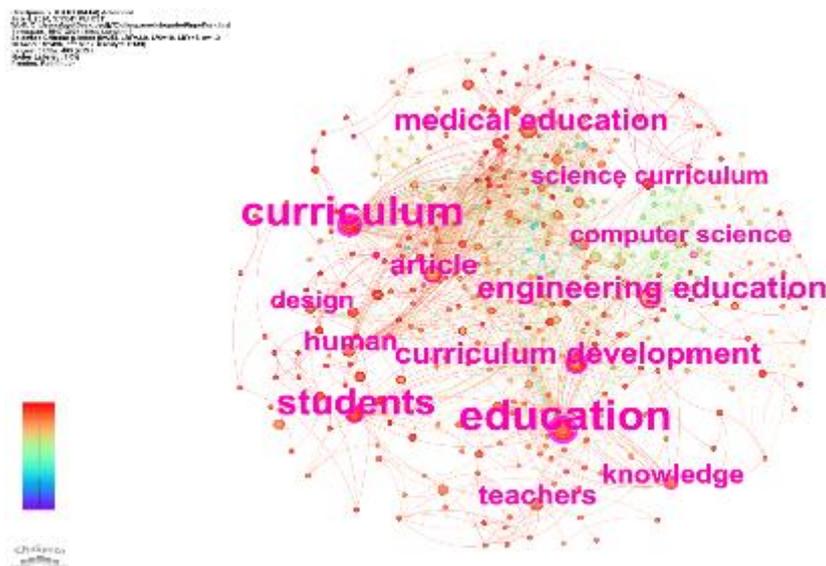


Figure 5. Keyword Co-occurrence Network in ISC Research (1947–2024)

Table 4

Top 10 High-Frequency Keywords in ISC Research (1947–2024)

count	centrality	co-occurrence
51	0.54	education
43	0.59	curriculum
26	0.2	students
15	0.18	engineering education
13	0.25	curriculum development
13	0.09	medical education
12	0.17	article
10	0.03	human
10	0.09	teachers
9	0.13	knowledge

Keyword Clustering Analysis

The clustering of keywords provides further insight into the thematic structures of ISC research, with a modularity Q of 0.7274 and silhouette value of 0.9232, indicating highly reliable results (Y. Chen et al., 2025). As illustrated in Figure 6, fifteen clusters were identified, reflecting diverse areas of inquiry.

The largest cluster (#0 Curriculum) emphasises course design, implementation, and evaluation, confirming the central role of curriculum in ISC scholarship. Related clusters include #2 Curriculum Development, which addresses planning and structural design, and #12 Evidence-Centered Design, highlighting the use of data-driven approaches for curriculum evaluation. Cluster #14 (Teaching Practices) underscores the importance of inquiry-based and blended pedagogies.

Beyond curriculum-focused themes, several clusters reflect interdisciplinary expansion. For example, #1 Computer Science, #4 Environmental Sustainability, #5 Nanoeducation, and #6 Interdisciplinary demonstrate the integration of emerging technologies and cross-disciplinary approaches into ISC. Other clusters, such as Anatomy, Pharmacology Education, and Science Curriculum, highlight the inclusion of specialised domains. Additionally, #10 Cultural Diversity points to the global and multicultural dimensions of ISC, while #8 Budget Control indicates attention to the economic factors that shape curriculum implementation.

Together, these clusters illustrate how ISC research has moved beyond traditional disciplinary boundaries to embrace a wider set of societal, technological, and cultural considerations.

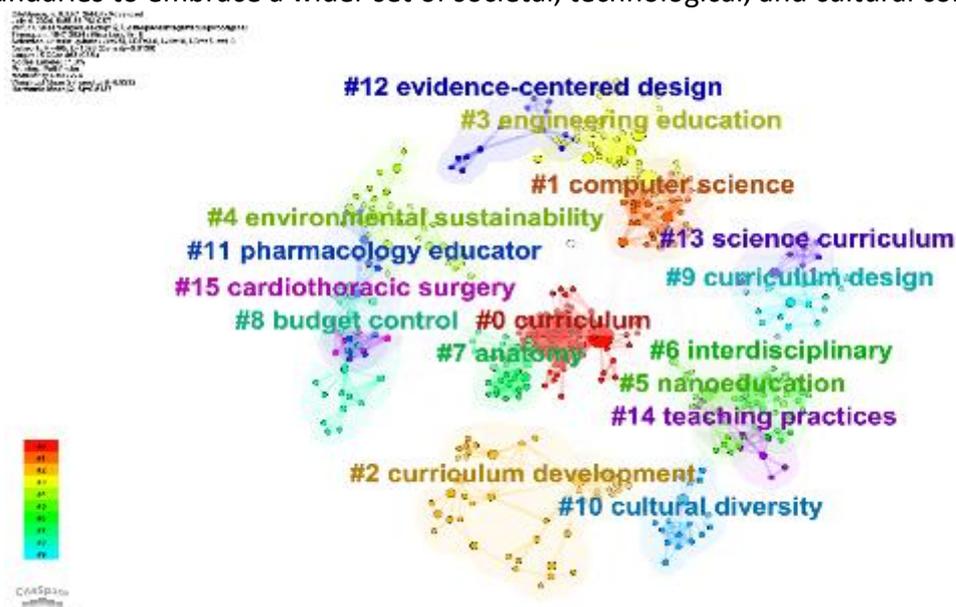


Figure 6. Keyword Clustering of ISC Research (1947–2024)

Keyword Burst Analysis

The burst analysis identifies periods when specific keywords experienced sharp increases in citation frequency, signalling the emergence of research frontiers. As illustrated in Figure 7, eleven keywords exhibited notable bursts across different time spans. For example, computer science (1993–1997, strength = 3.46) reflects the growing role of digital technologies in science education during the 1990s, while teaching (1993–2005, strength = 2.56) highlights early emphasis on pedagogy. More recently, integrated science (2017–2020) corresponds to the global expansion of interdisciplinary curricula, whereas science curriculum (2021–2024) and students (2022–2024) represent the current focus on curriculum reform and learner engagement.

These results indicate that the thematic emphasis of ISC research has shifted over time: from technological integration and pedagogy in earlier decades to student-centred approaches and curriculum innovation in recent years. The sustained bursts in domains such as engineering education and mathematics further underscore the long-standing influence of STEM frameworks on ISC scholarship.

Top 11 Keywords with the Strongest Citation Bursts



Figure 7. Keyword Burst Detection of ISC research (1947–2024)

Conclusion

This scientometric analysis of 350 ISC publications (1947–2024) identified clear developmental phases: marginal beginnings, gradual growth, and rapid expansion linked to STEM reforms, with a decline after 2020 due to COVID-19. Influential scholars such as Rochintaniawati and Froyd, together with leading institutions including Texas A&M University System, Purdue University, and the University of Florida, highlight the central role of the United States, alongside China and Canada, in shaping global ISC research. Keyword analyses reveal curriculum design, student learning, and interdisciplinary integration as enduring themes, with clusters extending into sustainability, computer science, and nanoeducation, while burst detection underscores recent emphasis on “science curriculum” and “students.” Overall, the field shows a trajectory toward interdisciplinarity and student-centred learning, yet evaluation-oriented studies remain limited, pointing to future needs for stronger international collaboration and systematic assessment of educational outcomes.

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