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Mapping Research on High School Chemistry Teaching Strategies (2020–2025): A Bibliometric Perspective

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Abstract

High school chemistry teaching strategies are a central topic in science education research, closely linked to student learning outcomes, core competencies, and curriculum reform. Although studies in science and chemistry education exist, systematic reviews on the development of high school chemistry teaching strategies in the past five years remain scarce. To address this gap, this study employs bibliometric and visualization methods to analyze the development characteristics and thematic evolution of related research between 2020 and 2025. The study draws on literature retrieved from the Web of Science database and applies bibliometric and keyword co-occurrence analysis, supported by visualization tools, to identify research features and knowledge structures in the field. The results show that between 2020 and 2025, the field exhibited a fluctuating rather than linear growth pattern. The United States maintained dominance, while several Asian countries demonstrated rapid growth. Research output was concentrated in a small number of representative universities and journals, reflecting strong academic influence. In terms of themes, inquiry-based learning and collaborative learning emerged as globally recognized core topics, while interdisciplinary integration, student-centered learning, and hands-on learning developed as secondary themes. Digital and tool-related topics remained marginal yet displayed potential for future growth. A comparison between database and author keywords revealed different emphases: database keywords highlighted methodological and structural issues, whereas author keywords emphasized disciplinary framing and researchers' representations. In conclusion, this study maps the knowledge structure and thematic evolution of research on high school chemistry teaching strategies, offering theoretical and bibliometric support for the systematic development of the field. The findings further suggest that future research should strengthen attention to digital learning, interdisciplinary integration, and contributions from Global South countries, thereby fostering more balanced development and sustained educational innovation.

Keywords: High School Chemistry, Teaching Strategies, Bibliometric Analysis, Research Trends, Inquiry-Based Learning, Collaborative Learning

Introduction

Teaching strategies in high school chemistry refer to the systematic approaches and methods employed by teachers to facilitate students' understanding of chemical concepts, laboratory skills, and problem-solving abilities (Ahmod & Zhang, 2021). These strategies can be broadly categorized into teacher-centered methods, such as lecture-based instruction and demonstration, and student-centered methods, including inquiry-based learning (IBL), problem-based learning (PBL), project-based learning (PjBL), and cooperative learning(Goodwin, 2024). Teacher-centered approaches emphasize knowledge transmission and curriculum coverage, while student-centered approaches highlight active engagement, critical thinking, and collaborative problem-solving(Goodwin, 2024).

Research has shown that diverse strategies exert different impacts on students' learning outcomes. For instance, inquiry-based and problem-based approaches have been found to significantly enhance students' conceptual understanding and motivation(Sugano & Nabua, 2020). Conversely, overreliance on lecture methods may restrict students' participation and reduce their opportunities for developing higher-order thinking skills(Antonio & Prudente, 2023). Furthermore, teaching strategies not only influence students' cognitive achievements but also shape their attitudes toward chemistry, their laboratory safety awareness, and their long-term scientific literacy(Antonio & Prudente, 2023; Qamariyah et al., 2021).

This study aims to analyze trends in publications on teaching strategies in high school chemistry from 2020 to 2025 using bibliometric analysis, providing insights for future research. Furthermore, it offers a visualization of current research trends in the field of high school chemistry teaching strategies. Data were collected from the Web of Science database to answer the following research questions:

RQ1: What is the yearly distribution of publications on high school chemistry teaching strategies between 2020 and 2025?

RQ2: Which countries and institutions have made the most significant contributions to this field during 2020–2025?

RQ3: Which journals and authors are most relevant and influential in high school chemistry teaching strategies research during this period?

RQ4: What are the primary keywords and research themes that have emerged in the field of high school chemistry teaching strategies from 2020 to 2025?

Method

This bibliometric study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) structure (Moher et al., 2009). Bibliometric analysis was applied to systematically identify, classify, and visualize research on teaching strategies in high school chemistry between 2020 and 2025.

Data Collection

All data were collected from the Web of Science (WoS) Core Collection database. The search strategy followed the principle of achieving comprehensive coverage while maintaining

precision, and was structured around three key concepts: teaching strategies, secondary-level education, and chemistry.

Teaching strategies: This component included a wide range of synonymous and related terms, such as Instructional Methods, Educational Practices, Teaching Strategies, Inquiry-Based Learning, Problem-Based Learning, Project-Based Learning, Collaborative Learning, Systems Thinking, Case-Based Learning, Laboratory Teaching, Field Trips, Internships and Practicum, Science Competitions and Challenges, Service Learning, Practicum Seminars, Research Groups, Thematic Inquiry, Task-Based Learning, Lecture Method, Discussion Method, Experimental Method, Role-Playing, and Case Study.

Secondary-level education: The search terms in this component included High School, Secondary Education, Secondary School, Pre-college, Pre-university, Secondary Chemistry, High School Chemistry, Secondary Science, and High School Science.
Chemistry: The term Chemistry was restricted to ensure that all retrieved publications were relevant to the discipline.

Regarding search logic, “OR” operators were used within each conceptual group to include all synonymous terms, while “AND” operators were applied across groups to ensure that the retrieved records simultaneously addressed teaching strategies, secondary-level education, and chemistry. As shown in Table 1.

To further enhance the scientific rigor and relevance of the results, several additional restrictions were applied: (i) the time span was limited to 2020–2025, reflecting recent research trends; (ii) only Articles were included, with Reviews, conference papers, book chapters, early access items, and other non-formal publications excluded; (iii) WoS categories were restricted to those closely related to education, chemistry, and sustainability (e.g., Education Educational Research, Education Scientific Disciplines, Chemistry Multidisciplinary), while unrelated categories (e.g., Social Sciences Interdisciplinary, Computer Science Interdisciplinary Applications, Engineering Chemical, Biology) were excluded. After merging and removing duplicates, a total of 173 unique publications were obtained, forming the dataset for bibliometric analysis in this study, as illustrated in Figure 1.

Table 1
The searching string used for database

Searching string and searching terms	**No.**	**acquisition Date**
TS=("Instructional Methods" OR "Educational Practices" OR "teaching strategies" OR "Inquiry-Based Learning" OR "Problem-Based Learning" OR "Collaborative Learning" OR "Systems Thinking" OR "Case-Based Learning" OR "Laboratory Teaching" OR "Project-Based Learning" OR "Field Trips" OR "Internships and Practicum" OR "Science Competitions and Challenges" OR "Service Learning" OR "Practicum Seminars" OR "Research Groups" OR "Thematic Inquiry" OR "Task-Based Learning" OR "Lecture Method" OR "Discussion Method" OR "Experimental Method" OR "Role-Playing" OR "Case Study") AND TS=("high school" OR "secondary education" OR "secondary school" OR "pre-college" OR "pre-university" OR "secondary chemistry" OR "high school chemistry" OR "secondary science" OR "high school science") AND TS=("chemistry")	486	18/05/2025

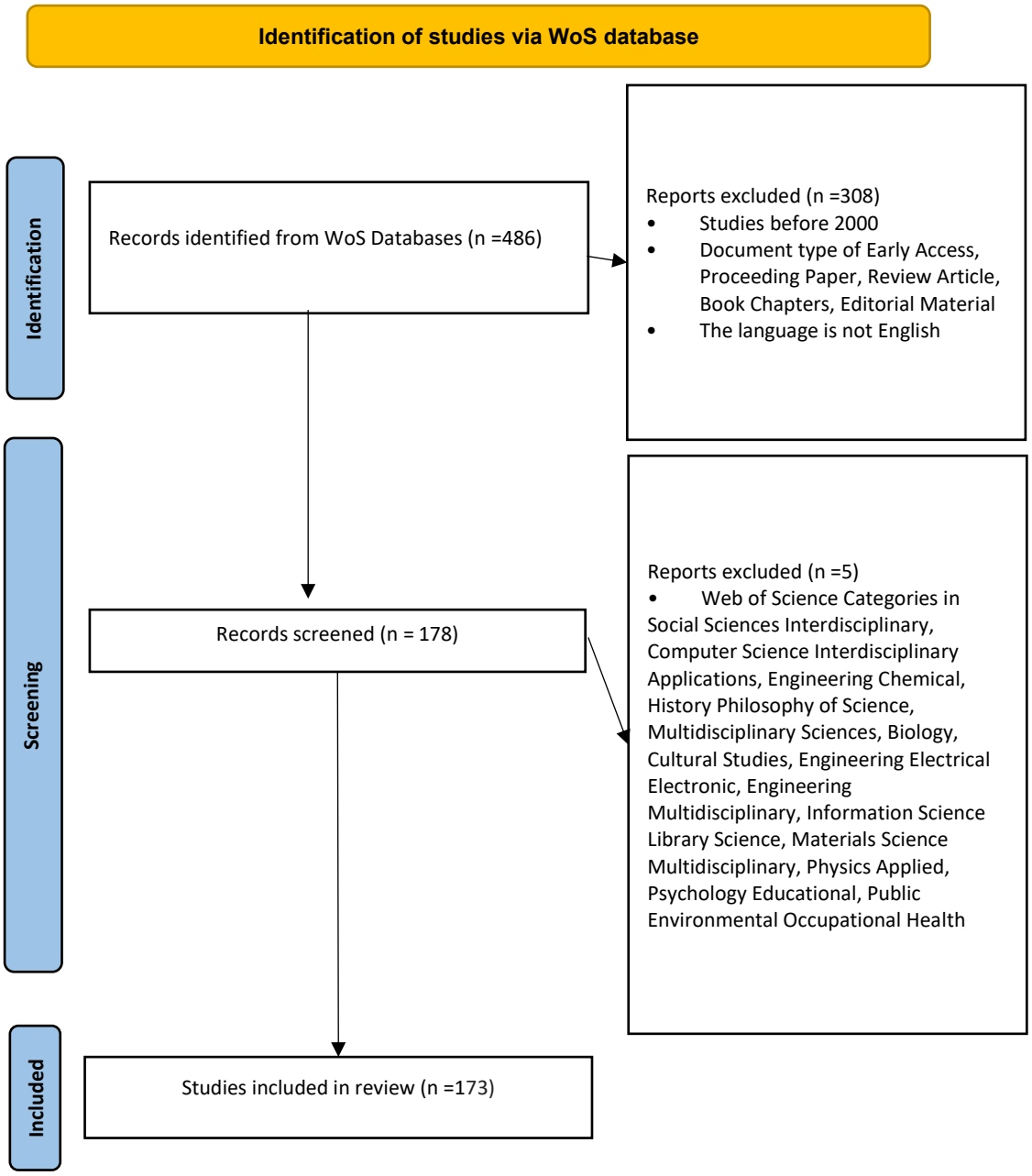

Figure 1 PRISMA 2020 Flow diagram for article selection (Page et al., 2021)

Result

This section presents the bibliometric findings on high school chemistry teaching strategies. Based on publications retrieved between 2020 and 2025, the analysis provides a comprehensive overview of this research field. The results address four key aspects: the yearly distribution of publications, the contributions of countries and institutions, the role of influential journals and authors, and the emergence of primary keywords and research themes. Together, these findings depict the current state and development patterns of research on high school chemistry teaching strategies, offering insights into its growth, structural features, and evolving directions.

3.1 Yearly distribution of publications (RQ1)

First, this study examines how research in the field of high school chemistry teaching strategies has evolved over time. As shown in Figure 2, the annual distribution of publications on high school chemistry teaching strategies between 2020 and 2025 presents a fluctuating pattern rather than a steady trend. The number of articles ranged from 23 in 2021 to a peak of 45 in 2024. Notably, publication counts increased significantly in 2022 (35) and reached the highest point in 2024 (45), before decreasing to 15 in 2025. The relatively low number in 2025 may be due to the fact that data for this year are incomplete at the time of analysis. Overall, while the field does not exhibit a consistent upward trajectory, the peaks in 2022 and 2024 suggest periods of heightened research activity in this domain.

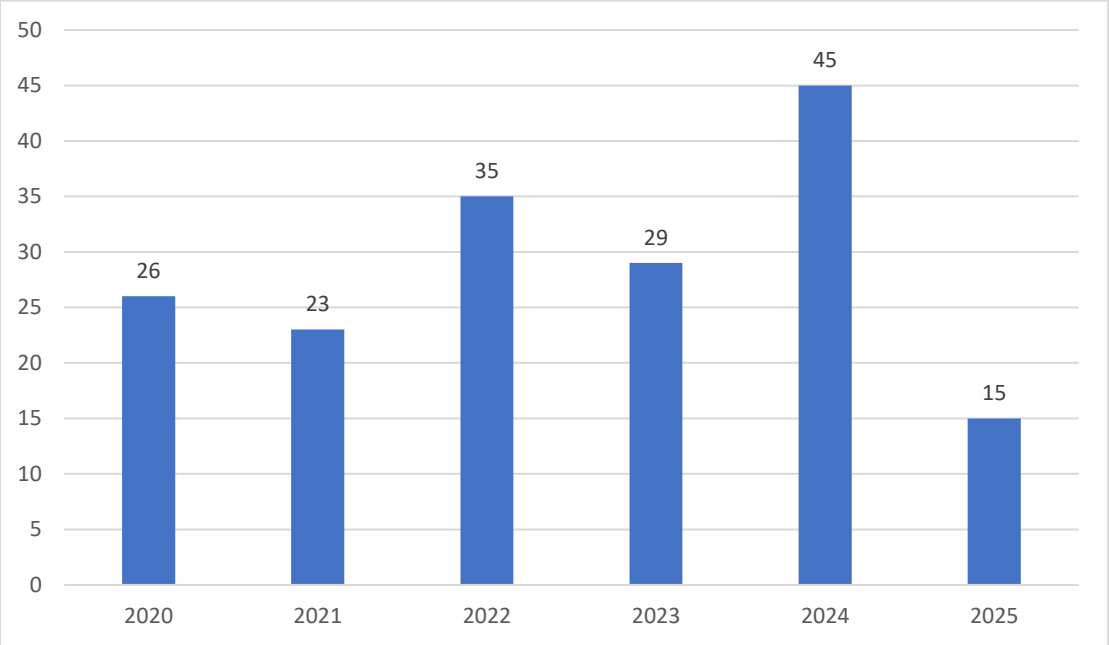

Figure 2 Number of reviewed articles by publication year (2020–2025)

Contributions of Countries and Institutions (RQ2)

To examine the geographical distribution of research in this field, Figure 3 presents the publication outputs of the top contributing countries between 2020 and 2025. During this period, the United States published the largest number of studies on high school chemistry teaching strategies, with a total of 33 articles. China ranked second with 13 publications, followed by Indonesia (11), Brazil and Germany (9 each), Malaysia and Spain (8 each), and Australia, England, and South Africa (7 each). These findings indicate that while the United States makes the largest contribution in terms of research output, several Asian countries such as China, Indonesia, and Malaysia have also shown increasing engagement. In addition, the participation of European countries (e.g., Germany, Spain, and England), along with Brazil and South Africa, suggests that research on high school chemistry teaching strategies extends across different regions. It should be noted that the dataset is derived from the Web of Science Core Collection and limited to English-language publications; therefore, relevant research published in local or non-English journals may not be represented.

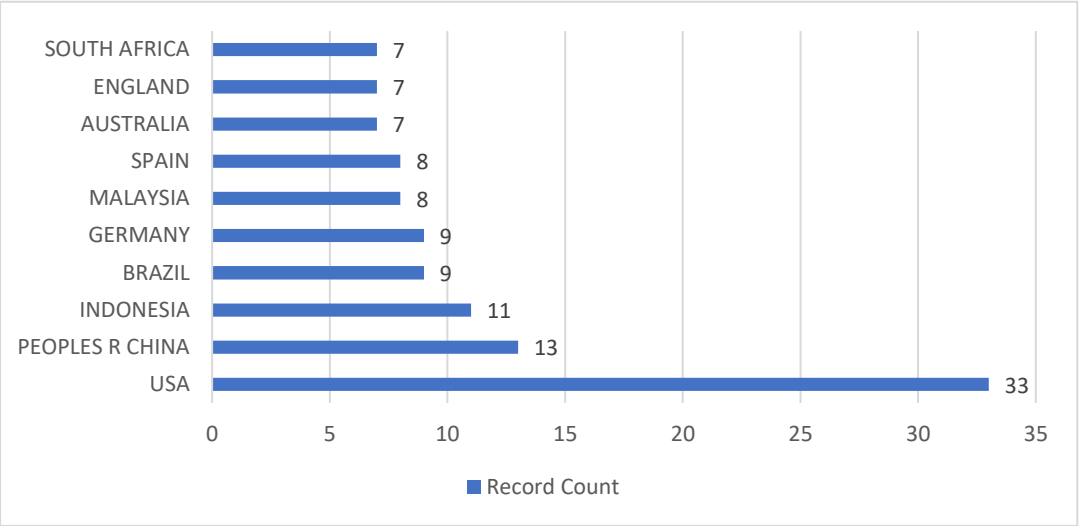

Figure 3 Top 10 Contributing Countries in High School Chemistry Teaching Strategies Research (2020–2025)

Table 2

Top 10 Countries and Their Most Significant Academic Institutions in High School Chemistry Teaching Strategies Research (2020–2025)

Rank	Country	TP	Most significant academic institution
1	USA	33	MICHIGAN STATE UNIVERSITY（TP=4） UNIVERSITY OF MICHIGAN（TP=4）UNIVERSITY OF MICHIGAN SYSTEM（TP=4）
2	CHINA	13	JIANGXI NORMAL UNIVERSITY（TP=3）
3	INDONESIA	11	UNIVERSITAS NEGERI MALANG（TP=3）
4	BRAZIL	9	INSTITUTO FEDERAL DA PARAIBA IFPB（TP=2） UNIVERSIDADE ESTADUAL DE CAMPINAS（TP=2） UNIVERSIDADE FEDERAL DE SAO CARLOS（TP=2）
5	GERMANY	9	UNIVERSITY OF BREMEN（TP=4）
6	MALAYSIA	8	INTI INTERNATIONAL UNIVERSITY（TP=2） SANZAC NATL SECONDARY SCH（TP=2） UNIVERSITI TEKNOLOGI MARA（TP=2） UNIVERSITY OF MALAYSIA SARAWAK（TP=2）
7	SPAIN	8	UNIVERSIDAD DE MALAGA（TP=3）
8	AUSTRALIA	7	DEAKIN UNIVERSITY（TP=5）
9	ENGLAND	7	UNIVERSITY OF LONDON（TP=2） UNIVERSITY OF YORK UK（TP=2）
10	SOUTH AFRICA	7	UNIVERSITY OF KWAZULU NATAL（TP=2）

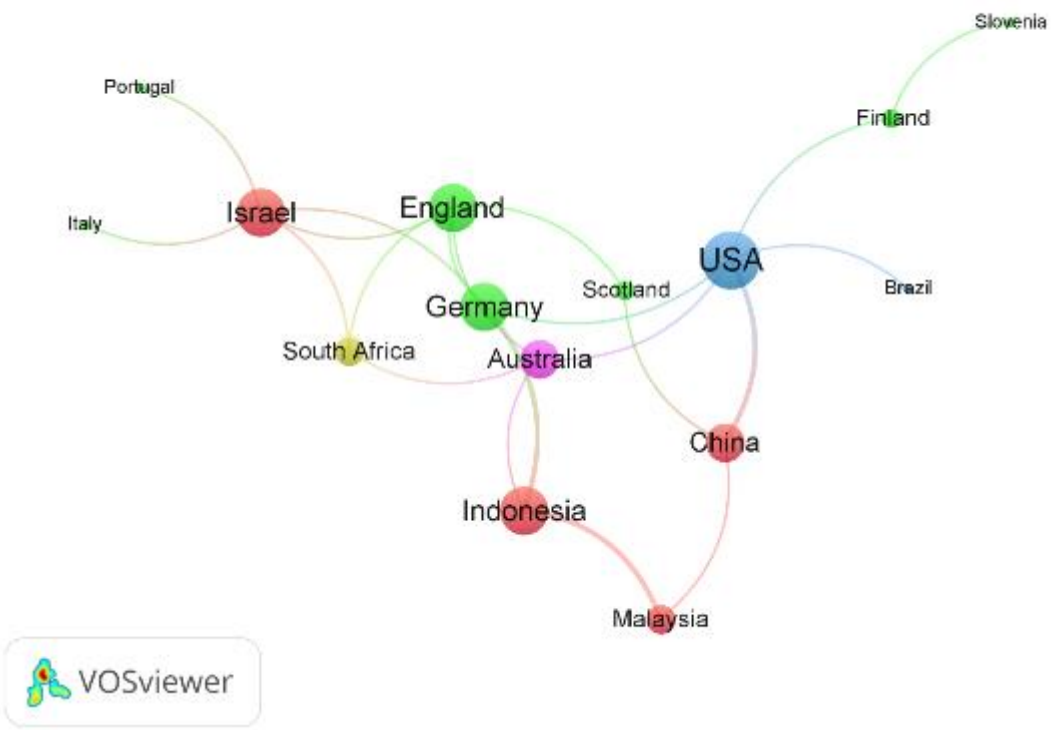

Figure 4 A map based on the relationship of co-authorship with countries

Beyond the country-level distribution, it is also important to consider the institutions driving this research activity. Table 2 lists the most significant academic institutions within the top 10 contributing countries. In the United States, institutions such as Michigan State University and the University of Michigan system each published four papers. In China, Jiangxi Normal University contributed three publications, while Universitas Negeri Malang in Indonesia produced three. In Germany, the University of Bremen published four papers. Brazil shows contributions from several federal universities, including Universidade Estadual de Campinas and Universidade Federal de São Carlos, each with two publications. In Malaysia, research outputs are distributed across multiple institutions, such as Universiti Teknologi MARA and INTI International University. Other representative institutions include Universidad de Málaga (Spain), Deakin University (Australia), University of York (England), and University of KwaZulu-Natal (South Africa). Taken together, the results show that in some countries contributions are concentrated within a small number of leading universities, while in others they are more evenly distributed across institutions.

In addition to publication counts, collaboration patterns provide further insights into the structure of this research field. Figure 4 shows the international co-authorship network, which reflects both research output (measured by occurrences, OC) and collaboration strength (measured by total link strength, TLS). In the Americas, the United States dominates the field with the highest number of publications (OC=35) and a considerable level of collaboration strength (TLS=6). In Asia, China stands out with both substantial output (OC=14) and the highest collaboration strength (TLS=24), followed by Indonesia (OC=11, TLS=5), Israel (OC=6, TLS=5), and Malaysia (OC=8, TLS=3). In Europe, the United Kingdom (OC=10, TLS=7) and

Germany (OC=10, TLS=5) are the main contributors, while Finland, Italy, Portugal, and Slovenia show more limited involvement. Among countries in the Southern Hemisphere, Australia (OC=7, TLS=4) and South Africa (OC=7, TLS=3) demonstrate visible participation, whereas Brazil (OC=9, TLS=1) shows moderate productivity but relatively weak collaboration intensity.

Overall, the results highlight that the United States is the global leader in terms of research output, while China occupies the strongest position with respect to collaboration intensity. Meanwhile, European and Asian countries contribute through regional cooperation, and Australia and South Africa provide additional links within cross-regional networks.

Influential Journals and Authors (RQ3)

To better understand the publication landscape of high school chemistry teaching strategies research, an analysis of the most relevant journals was conducted. Table 3 presents detailed information on the top contributing journals, including total publications (TP), total citations (TC), citation score, most cited article, and publisher. the Journal of Chemical Education ranks first, with 72 publications, 476 citations, and a citation score of 168 in 2024. Its most cited article, “Making Every Second Count: Utilizing TikTok and Systems Thinking to Facilitate Scientific Public Engagement and Contextualization of Chemistry at Home”, has been cited 61 times. Following this, Chemistry Education Research and Practice, published by the Royal Society of Chemistry, contributed 10 articles with a total of 119 citations and a citation score of 39 in 2024. Its most cited work, addressing “Trends and perceptions of choosing chemistry as a major and a career,” has been cited 55 times. Other journals with relevant contributions include Education Sciences (9 publications, 27 citations), the Journal of Baltic Science Education (7 publications, 14 citations), and Chemistry Teacher International (6 publications, 10 citations). These journals, while publishing fewer papers, reflect the wider range of platforms supporting research in this field.

Table 3
Top 5 Contributing Journals in High School Chemistry Teaching Strategies Research (2020–2025)

Journal	TP	TC	Citation Score (2024)	Most cited article	Times Cited	Publisher
JOURNAL OF CHEMICAL EDUCATION	72	476	168	"Making Every Second Count": Utilizing TikTok and Systems Thinking to Facilitate Scientific Public Engagement and Contextualization of Chemistry at Home	61	Amer Chemical Soc
CHEMISTRY EDUCATION RESEARCH AND PRACTICE	10	119	39	Trends and perceptions of choosing chemistry as a major and a career	55	Royal Soc Chemistry
EDUCATION SCIENCES	9	27	13	Using Systems Maps to Visualize Chemistry Processes: Practitioner and Student Insights	9	Mdpi

JOURNAL OF BALTIC SCIENCE EDUCATION	7	14	6	EFFECT OF TASK-BASED LEARNING ON STUDENTS' UNDERSTANDING OF CHEMICAL REACTIONS AMONG SELECTED RWANDAN LOWER SECONDARY SCHOOL STUDENTS	6	Sci Methodical Ctr-Sci Educologica
CHEMISTRY TEACHER INTERNATIONAL	6	10	3	Kitchen chemistry course for chemistry education students: influences on chemistry teaching and teacher education - a multiple case study	6	Walter De Gruyter

TP= total publications, TC= total citation

Table 4 presents the most productive scholars in the field of high school chemistry teaching strategies research between 2020 and 2025 in WoS. Notably, Delaney from Deakin University, Australia, stands out with five publications, indicating the university's active engagement in advancing chemistry education research. Eilks from the University of Bremen, Germany, also occupies a prominent position, having published four papers and received the highest citation count (39), which reflects substantial scholarly output and influence. Schultz, likewise from Deakin University, produced four publications, further suggesting that the institution has developed a relatively strong research cluster in this area.

It is also noteworthy that several scholars from Michigan State University in the United States (Krajcik, Schneider, and Touitou) each contributed three papers with relatively high citation counts (30), underscoring the university's international leadership in inquiry-based and project-based learning. In Southern Europe, Franco-Mariscal from the Universidad de Málaga, Spain, demonstrates comparable productivity with a citation count of 33, highlighting the region's engagement with pedagogical innovation. Morais from the Universidade do Porto, Portugal, also adds to Europe's overall contribution, though with relatively fewer citations. In the Global South, Oladejo and Olateju from Lagos State University, Nigeria, each published three papers, showing that African scholars have achieved a certain level of participation in this field. Similarly, Walag from the University of Science and Technology of Southern Philippines has three publications, but with a lower citation record, suggesting that the international visibility of research in this region is still developing.

Overall, the main research strength in this field is concentrated in Europe (Germany, Spain, Portugal), Oceania (Australia), and North America (United States), while contributions from African and Asian scholars are gradually increasing. This distribution pattern indicates that research on high school chemistry teaching strategies has achieved a certain degree of internationalization, although disparities in influence across regions remain evident.

Table 4
Most Productive Authors in High School Chemistry Teaching Strategies Research (2020–2025)

Author	TP	TC	h-index	Current Affiliation	Country
Delaney, S.	5	21	2	Deakin University	Australia
Eilks, I.	4	39	3	University of Bremen	Germany
Schultz, M.	4	20	2	Deakin University	Australia
Franco-Mariscal, A.J.	3	33	3	Universidad de Málaga	Spain
Krajcik, J.	3	30	2	Michigan State University	USA
Morais, C.	3	12	2	Universidade do Porto	Portugal
Oladejo, A.I.	3	18	2	Lagos State University	Nigeria
Olateju, T.T.	3	18	2	Lagos State University	Nigeria
Schneider, B.	3	30	2	Michigan State University	USA
Touitou, I.	3	30	2	Michigan State University	USA
Walag, A.M.	3	7	2	University of Science and Technology of Southern Philippines	Philippines

TP= total publications, TC= total citation

3.4 Research keywords and themes (RQ4)

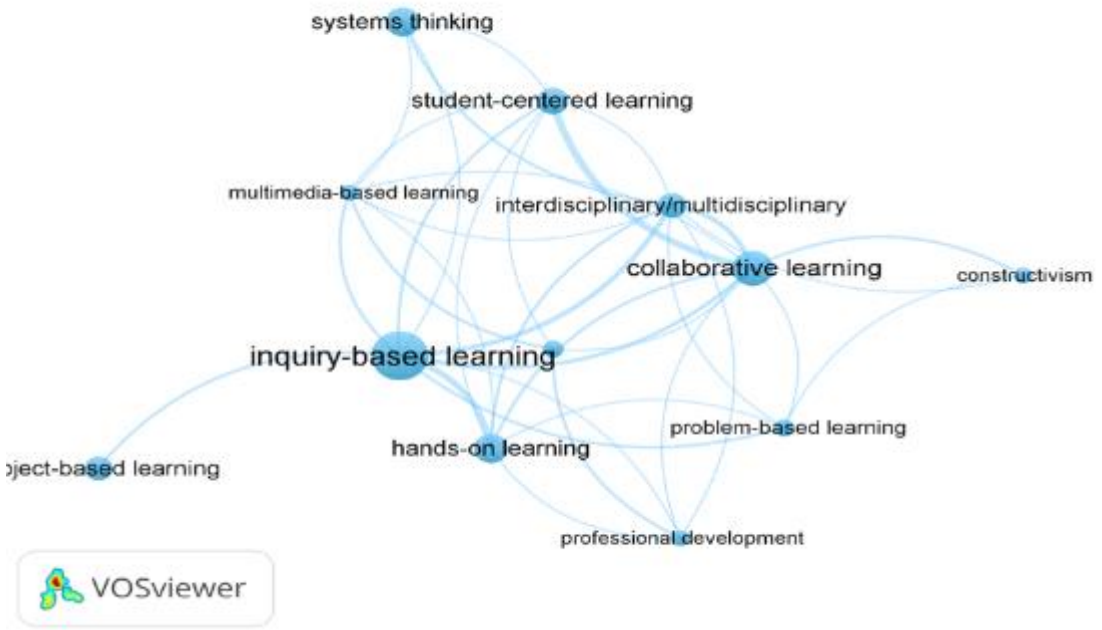

Figure 5. A map based on the relationship of co-occurrence with all keywords in high school chemistry teaching strategies

Figure 5 illustrates the co-occurrence map of all keywords related to high school chemistry teaching strategies. As shown in the data, *inquiry-based learning* emerged as the most frequently occurring term (OC=33, TLS=22), highlighting its central position in the network. This was followed by *collaborative learning* (OC=19, TLS=21) and *hands-on learning* (OC=14, TLS=13), both of which also demonstrated strong connectivity with other keywords.

Other frequently appearing terms included *student-centered learning* (OC=12, TLS=13) and *project-based learning* (OC=10, TLS=2), while *interdisciplinary/multidisciplinary* (OC=11, TLS=17) and *systems thinking* (OC=14, TLS=5) also formed notable clusters in the map. In

addition, several keywords appeared less frequently, such as *constructivism* (OC=5, TLS=4), *professional development* (OC=5, TLS=6), and *multimedia-based learning* (OC=5, TLS=9). Keywords linked to digital approaches, such as *internet/web-based learning* (OC=6, TLS=6), were present but less central compared to the dominant terms.
Overall, the map indicates that research in this field is structured around inquiry-based and collaborative forms of learning, with complementary attention to student-centered, hands-on, and interdisciplinary approaches.

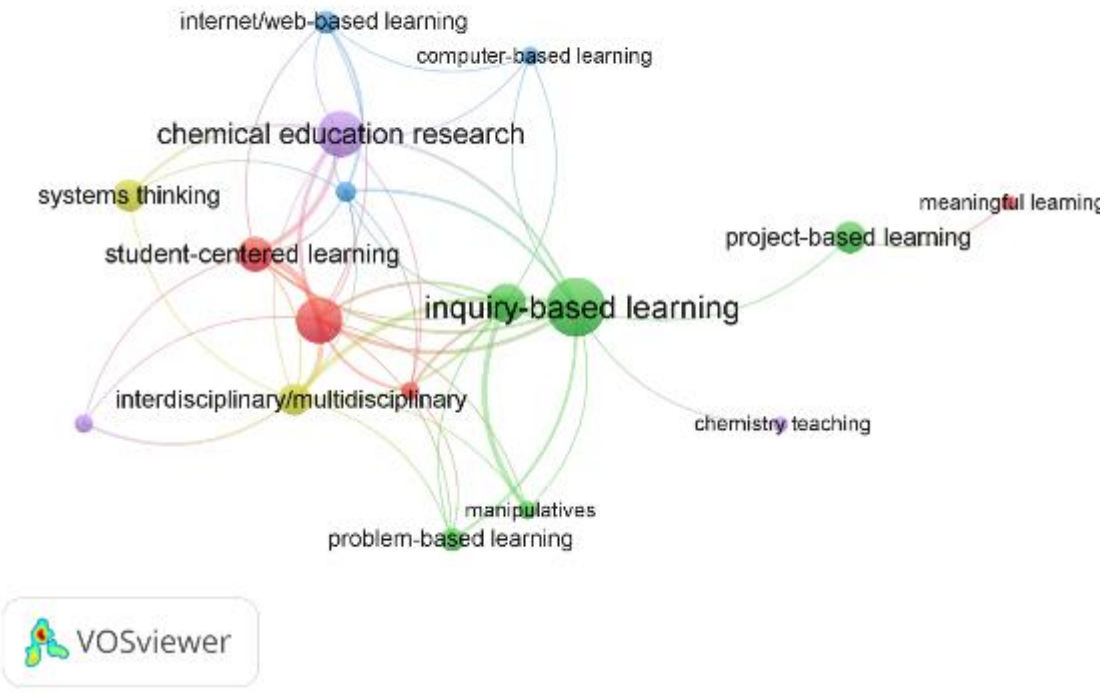

Figure 6. A map based on the relationship of co-occurrence with author keywords in high school chemistry teaching strategies

Figure 6 presents the co-occurrence map of author-provided keywords in high school chemistry teaching strategies. *Inquiry-based learning* again appeared as the most frequent term (OC=28, TLS=26), confirming its central role in the network. *Collaborative learning* (OC=19, TLS=25) and *chemical education research* (OC=19, TLS=16) also showed high frequencies and strong connections, indicating that they are consistently emphasized by authors in framing their studies.

Other prominent keywords included *hands-on learning* (OC=14, TLS=17), *student-centered learning* (OC=12, TLS=17), and *interdisciplinary/multidisciplinary* (OC=10, TLS=18), suggesting their widespread use as descriptors in author keyword lists. Additionally, *systems thinking* (OC=10, TLS=4) and *project-based learning* (OC=10, TLS=2) appeared with moderate frequency but weaker link strengths compared to the dominant terms.

Less frequent keywords included *internet/web-based learning* (OC=6, TLS=6), *problem-based learning* (OC=6, TLS=6), and *multimedia-based learning* (OC=5, TLS=11), as well as lower-

frequency terms such as *communication/writing* (OC=4, TLS=7), *manipulatives* (OC=4, TLS=7), *analogies/transfer* (OC=4, TLS=4), *chemistry teaching* (OC=3, TLS=1), and *meaningful learning* (OC=3, TLS=1).

Overall, the author keyword co-occurrence map highlights a strong emphasis on inquiry-oriented and collaborative approaches, complemented by terms reflecting student-centered, hands-on, and interdisciplinary perspectives.

Discussion

This section discusses the review findings in relation to the four research questions. The results have already presented descriptive analyses of publication trends, country and institutional contributions, the impact of core journals and authors, and the distribution of keywords and research themes. The aim here is to interpret these findings and situate them within the broader literature, thereby highlighting their implications for theory, practice, and policy.

The analysis of publication trends between 2020 and 2025 shows that the field has developed in a fluctuating manner rather than through continuous growth. Unlike some areas of science education research that display long-term linear increases(Chiu et al., 2025) , studies on high school chemistry teaching strategies appear to be more sensitive to external conditions and stage-specific issues. The peaks in 2022 and 2024 may be linked to rising international and national attention to inquiry-based learning, core competencies, and curriculum reform at that time(UNESCO, 2024). In contrast, the relatively low output in 2021 may reflect the disruptions to school teaching and educational research caused by the COVID-19 pandemic(Cretu & Ho, 2023). Overall, this fluctuating trend suggests that development in this field is not marked by steady expansion but is closely tied to education reforms, research agendas, and broader social contexts at particular times. This finding echoes observations in existing reviews of chemistry education about uneven growth patterns [reference needed] and further indicates that research in the high school context is strongly shaped by external driving forces.

The geographical distribution of publications shows marked regional differences in research activity. The United States remains the leading country in terms of output, with its research strength reflected not only in quantity but also in a concentration within a few representative universities, such as Michigan State University. This pattern highlights its long-standing tradition and well-established support system in inquiry-based learning, STEM education, and project-oriented teaching(Simamora, 2024). However, from the perspective of collaboration networks, while the United States produces a large number of studies, the overall intensity of collaboration is relatively limited, suggesting that there is still room to expand international cooperation.

In comparison, Asian countries have shown increasing research activity. China ranks second in publication output and, according to this study, stands out for its strong international collaboration (TLS = 24), gradually taking on the role of a hub for cross-national research(Marginson, 2022). Indonesia and Malaysia have also been expanding their research presence. Although these publications are distributed across multiple institutions, they reflect the growing potential of a regional research community. In Europe, the United Kingdom and

Germany remain active in collaboration networks, with a stronger focus on regional cooperation. Institutions such as the University of Bremen and the University of Málaga in Spain have made concentrated contributions to the field. In the Southern Hemisphere, Australia and South Africa, despite their relatively limited output, maintain a presence in cross-regional collaborations, providing complementary connections to the global network. Overall, the global research landscape in this field is shaped not only by publication output but also by collaboration intensity and the distribution of research communities.

To explore the research themes in greater depth, this study analyzes both the database-extracted keywords and the author-provided keywords. This combined perspective not only reveals the consistency of research around common focal points but also highlights the differences between literature indexing and researchers' own framing.

In terms of research themes, both database and author keywords place inquiry-based learning and collaborative learning at the center, reflecting a global consensus on these approaches as mainstream teaching strategies(Jegstad, 2023; Marreh & Velankar, 2024; Urdanivia Alarcon et al., 2023). At the same time, notable differences can be observed between the two types of keywords. Database-extracted keywords tend to emphasize methodological and structural aspects, such as systems thinking and professional development(Chen & Xiao, 2016), whereas author keywords more often highlight chemical education research. This difference, as shown in our analysis, suggests that database indexing captures broader methodological concerns, while author keywords reflect how researchers frame and represent their work within the field.

In addition, secondary themes such as student-centered learning, hands-on learning, project-based learning, and interdisciplinary approaches reflect a continued focus on instructional innovation and cross-disciplinary integration. By contrast, lower-frequency keywords such as internet/web-based learning, multimedia learning, manipulatives, and communication/writing suggest that topics related to technological support and tool application remain at the margins for now, though they hold potential for further development in the future(Chiu, 2021).

Overall, these results reveal both the core consensus and the differentiated features of research theme selection in high school chemistry teaching strategies, while also pointing to emerging directions that deserve further exploration.

Conclusion

This study systematically reviewed the literature on high school chemistry teaching strategies published between 2020 and 2025, highlighting the field's development in terms of annual distribution, country and institutional contributions, and research themes. The results show that the field has generally followed a fluctuating growth trend, with research power concentrated in the United States. At the same time, some Asian countries have surpassed Europe in publication output, reflecting the region's rapid rise and active participation. In Europe and Oceania, academic influence has been sustained mainly by a few universities and research groups. Keyword and theme analyses further indicate that inquiry-based learning and collaborative learning have become globally recognized core topics, while directions such

as student-centered learning, interdisciplinary integration, and hands-on learning reflect diverse and innovative explorations.

Compared with existing reviews, this study not only outlines the overall landscape of the literature but also reveals differences in research themes between external indexing and researchers' own positioning through a comparison of database keywords and author keywords. This integrated perspective helps to provide a more comprehensive understanding of the knowledge structure and thematic evolution of research on high school chemistry teaching strategies, offering both theoretical grounding and literature support for future studies. Going forward, more attention could be given to digital learning, interdisciplinary integration, and the contributions of Global South countries, in order to promote balanced development and innovation in educational practice.

Limitations

This study also has several limitations. First, the literature search relied solely on the Web of Science database and did not include relevant studies from other databases, which may have resulted in the omission of some research. Second, the keywords used in the search were mainly focused on "high school chemistry teaching strategies" and directly related terms. Although efforts were made to consider a wide range of expressions, some studies on teaching methods or classroom practices may still have been overlooked. Finally, this review included only publications written in English and did not cover studies published in other languages, which limits the comprehensiveness and representativeness of the findings to some extent.

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