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Global Trends and Collaborations in AI-Based Chemistry Education Research: A Bibliometric Analysis

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Abstract: In recent years, the integration of artificial intelligence (AI) into chemistry education has attracted increasing attention, leading to a growing body of research in this field. This study offers an in-depth bibliometric examination of publications focusing on artificial intelligence (AI) in chemistry education during the period 2021–2025. The data were retrieved from the Web of Science database, and the analysis was conducted using VOSviewer. A total of 972 publications meeting the defined criteria were identified. The yearly distribution of publications reveals a significant upward trend in research output, reaching its highest level in 2025. At the country level, the United States, China, and Germany were identified as the primary contributors to the field. In addition, the most productive authors were M. Cooper, R. L. Stowe, and R. Blonder. With respect to journal productivity and citation impact, the Journal of Chemical Education was identified as the most prominent source. University of South Florida, Michigan State University and University of Iowa are the most productive universities. Keyword co-occurrence analysis revealed that the most frequently used terms included "Undergraduate Education", "Chemistry Education" and "General Chemistry". Overall, these findings provide valuable insights into recent developments and emerging trends in AI research within chemistry education. The study is expected to support researchers in identifying key research directions and to inform future investigations in this rapidly evolving field.

Keywords: Artificial intelligence, Bibliometric analysis, Chemistry education, VOSviewer

Introduction

In the 21st century, characterized by rapid technological advancements, educational systems have undergone a profound transformation under the influence of these developments. This transformation has not only led to the digitalization of learning environments but has also necessitated the restructuring of teaching and learning processes, thereby creating greater opportunities for equity in education (Holmes et al., 2019; Sürer, 2020). With the increasing emphasis on 21st-century skills, equipping individuals with competencies such as critical thinking, problem-solving and decision-making, and data literacy has become a primary objective of modern education systems (Voogt & Roblin, 2012; Çittir et al., 2025).

In this context, the integration of innovative technologies into education has gained significant importance. The transformation of educational tools in line with technological progress has made learning experiences more interactive, participatory, and personalized. Among these technologies, artificial intelligence has emerged as one of the most prominent developments in the field of education in recent years (Buluş & Elmas, 2024; Temur, 2024). Artificial intelligence applications offer substantial opportunities, including the personalization of learning processes, enhancement of student engagement, support for learning through peer interaction, real-time monitoring and analysis of student performance, adaptation of instructional materials, and the provision of data-

driven feedback to teachers. In this regard, artificial intelligence is considered not merely a technological tool but a transformative force that reshapes learning processes (Holmes et al., 2019; Erümit & Sarıalioğlu, 2025).
The use of AI-supported systems in education enables advantages such as real-time tracking and analysis of student data, identification of individual learner needs, and the provision of personalized resources (Karabacak et al., 2025). In particular, AI-based systems are reported to be effective in identifying and addressing misconceptions by offering instant feedback tailored to students' learning states, preferences, and individual characteristics, thereby facilitating personalized learning guidance (Hwang et al., 2020).

Chemistry is regarded as a fundamental and central science across a wide range of fields, including medicine, pharmacy, biochemistry, engineering, agriculture and animal sciences, and space sciences, and it continues to evolve steadily. In this respect, advancements in chemistry education contribute not only to its own domain but also to the development of other disciplines (Eljack, 2020; Yazıcı, 2024). By its nature, chemistry encompasses numerous abstract concepts that are not directly observable. Combined with its unique symbolic language and the difficulty students experience in establishing meaningful connections among macroscopic, molecular, and symbolic levels of representation, chemistry is often considered a challenging subject to learn and teach. Moreover, these challenges may lead students to struggle with conceptual understanding and, consequently, to rely on rote memorization in their learning processes (Pekdağ, 2010; Berg et al., 2019; Laohapornchaiphan & Chenprakhon, 2024).

In addition, laboratory practices—an essential component of chemistry education grounded in experiential learning—cannot always be implemented at the desired level due to factors such as cost, safety, and accessibility. This limitation constitutes a significant constraint on the learning process and increases the need for interactive and alternative instructional approaches that promote active student participation (Kavlak & Birhanlı, 2023). In recent years, rapidly advancing artificial intelligence technologies have emerged as a promising solution in chemistry education, with their potential to personalize learning processes, analyze students' conceptual understanding, and provide adaptive learning environments (Chen et al., 2020; Zaharullila, 2025).

AI-supported applications, as in other subject areas, can identify students' learning gaps in chemistry and provide feedback tailored to individual performance levels, thereby supporting learners according to their own pace and needs. This, in turn, assists teachers in planning, implementing, and evaluating instruction more effectively, making chemistry lessons more engaging and helping students achieve their individual learning goals. Consequently, differentiated learning approaches can also be facilitated (Buluş & Elmas, 2024; Huwer et al., 2025). Furthermore, the potential of artificial intelligence to simplify complex chemistry topics and enhance learning adds a significant dimension to educational research (Erümit & Sarıalioğlu, 2025).

In this study, a bibliometric analysis method was employed to provide a comprehensive and holistic overview of the general trends, focal points, developmental processes, and scientific productivity structure of artificial intelligence applications that are increasingly prevalent in chemistry education. Bibliometric analysis is widely used by researchers for various purposes, such as identifying emerging trends in article and journal performance, revealing collaboration networks, and uncovering the intellectual structure of a specific research field within the existing literature (Donthu et al., 2021). Through this bibliometric analysis, the distribution of studies on artificial intelligence in chemistry education over the years was examined, along with the most influential authors, journals, universities, and countries. In addition, keyword analysis was conducted to evaluate the current state of the field and its developmental trajectories in a comprehensive manner. Furthermore, this bibliometric study on artificial intelligence in chemistry education is expected to contribute to the identification of research gaps in the existing literature and to provide guidance for future studies in the field.

This study seeks to address the following research questions:

1. How are relevant publications distributed over time?
2. Which countries demonstrate the highest levels of publication productivity?
3. Which authors can be considered the most productive and influential in this research field?
4. Which authors are most commonly co-cited within the existing literature?
5. Which journals receive the highest number of citations within the field?
6. Which universities receive the highest number of citations within the field?
7. What are the main patterns and emerging trends in keyword usage within the existing literature?

Method

This study utilizes a bibliometric approach to investigate the current landscape of international publications on the application of artificial intelligence in chemistry education, as indexed in the Web of Science (WoS) database. Bibliometric analysis is a quantitative method used to explore the structural characteristics of scientific publications within a given research domain, offering a systematic and comprehensive overview of the existing body of literature (Guo et al., 2024; Ulukök Yıldırım & Sönmez, 2024). This study aims to collect data from studies on artificial intelligence in the field of chemistry education—such as authors, keywords, cited authors, and countries—and to examine these data through statistical methods. Furthermore, it seeks to analyze the results in light of these statistical findings and to construct network maps that reveal the structural relationships within the field.

Limitations of the Study

The primary limitation of this study is that it includes only publications in English. Since the current year has not yet concluded, publications from 2026 were not included in the analysis. Furthermore, the restriction to selected titles for network mapping constitutes an additional limitation of the research.

Data Collection Process

A comprehensive search was conducted using the Web of Science (WoS) database to identify relevant literature. The WoS database was selected due to its extensive and reliable coverage of bibliometric data on a global scale, and its frequent use as a primary data source in bibliometric research (Ulukok-Yildirim & Sonmez, 2025). In this study, the time frame between 2021 and 2025 was adopted in order to reveal the current state of scientific publications in the field of chemistry education over the last five years. The data were retrieved from the Web of Science (WoS) database on March 18, 2026. General information regarding scientific publications on artificial intelligence in chemistry education is presented in Table 1. Within the specified time frame, a total of 1518 records focusing on artificial intelligence in chemistry education were identified. Among these, 1320 were classified as articles. Of these studies, 1255 publications written in English were included in the analysis. When the indexes SCI-EXPANDED, SSCI, A&HCI, and ESCI were selected, the number of articles decreased to 1249. As a final filtering step, limiting the research area to "Education & Educational Research" resulted in a total of 972 articles included in the study.

Table 1. Article selection process

Parameter	Details
Database	WoS
Keywords	("artificial intelligence" OR "AI" OR "AIED" OR "machine learning" OR "intelligent tutoring system" OR "expert system" OR "recommended system" OR "recommendation system" OR "feedback system" OR "personalized learning" OR "adaptive learning" OR "prediction system" OR "student model" OR "learner model" OR "data mining" OR "learning analytics" OR "prediction model" OR "automated evaluation" OR "automated assessment" OR "robot" OR "natural language processing" OR "virtual agent" OR "algorithm" OR "machine intelligence" OR "intelligent support" OR "intelligent system" OR "deep learning" OR "AI education") AND ("chemistry educat*")
Research Area	Education Educational Research
Publication Type	Article
Publication Years	2021-2025
Indexes	SCI-EXPANDED, SSCI, A&HCI, ESCI
Languages	English
Date	18 March 2026

Data Analysis

In this study, bibliographic data of 972 records retrieved from the Web of Science were imported into VOSviewer (version 1.6.20), a software tool designed for constructing and analyzing bibliometric networks. Developed by Van Eck and Waltman (2010), VOSviewer enables the visualization of bibliometric relationships using a distance-based mapping approach. The software supports text mining based on keywords and abstract terms, as well as citation and co-citation analyses, and offers functionalities such as overlay visualization, density mapping, and network exploration (Van Eck & Waltman, 2023). Within this framework, the analysis focused on several variables, including publication year, country, journal, citations, co-citations, institutions, and keywords. Prior to conducting the analyses, the dataset was carefully examined and subjected to data cleaning procedures.

Results and Discussion

Annual Scientific Production

Figure 1 presents the annual distribution of scientific publications and citation counts related to artificial intelligence in chemistry education over the period 2021–2025.

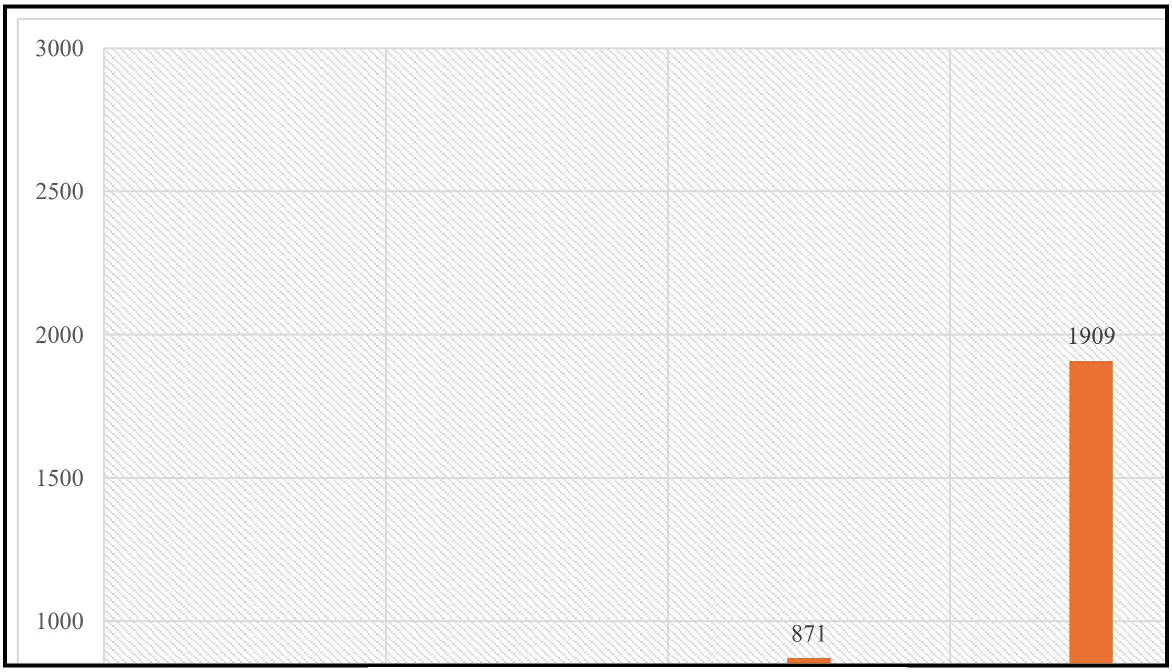

Figure 1. Output of the number of publications and citations

The distribution of the number of scientific publications and citations on artificial intelligence in the field of chemistry education is illustrated in Figure 1. Studies conducted over a five-year period, covering 2021–2025, were included in the analysis. As shown in Figure 1, the highest number of publications was recorded in 2025, with a total of 241 studies, while the same year also received the highest number of citations, totaling 2703. Overall, the increase in both the number of publications and citations on artificial intelligence in chemistry education demonstrates a parallel upward trend over the years. This observed pattern indicates a growing scholarly interest in the integration of artificial intelligence into chemistry education, accompanied by a substantial increase in research activity and the ongoing dynamic development of the field.

Although research on artificial intelligence in chemistry education is still in its early stages, the consistent growth observed over time suggests that the field is experiencing a rapid and ongoing transformation. In particular, the notable rise observed in 2025, both in terms of the number of publications (241 studies) and citations (2703 citations), suggests that this topic has gained significant scientific impact, that the body of knowledge in the literature is expanding rapidly, and that studies are increasingly building upon one another (Sari & Ahmad, 2025; Erümit & Sarialioğlu, 2025; Iyamuremye, 2024). The widespread adoption of artificial intelligence technologies and data-driven learning approaches in educational settings in recent years can be considered one of the main drivers of this rapid growth. In addition, increased accessibility to AI tools has facilitated the involvement of researchers from diverse disciplines, thereby enhancing the diversity and scope of research in this field (Yuriev et al., 2024; Akyel & Tur, 2024).

Distribution of Publications Across Countries

Table 2 presents the geographical distribution of the publications included in the analysis. To identify the most productive countries in terms of scientific output, a minimum criterion of 10 documents and at least one citation was established. The analysis was carried out based on 26 units of observation, reflecting the interrelationships among countries.

Table 2. Distribution of publications across the top ten countries

Rank	Country/Region	Number of publications	Citation	TLS
1	USA	353	3164	306
2	China	90	388	84
3	Germany	74	392	78
4	Türkiye	40	167	33
5	England	33	356	52
6	Spain	32	130	19
7	Australia	27	128	43
8	Brazil	27	108	34
9	Indonesia	26	151	20
10	Canada	25	220	49

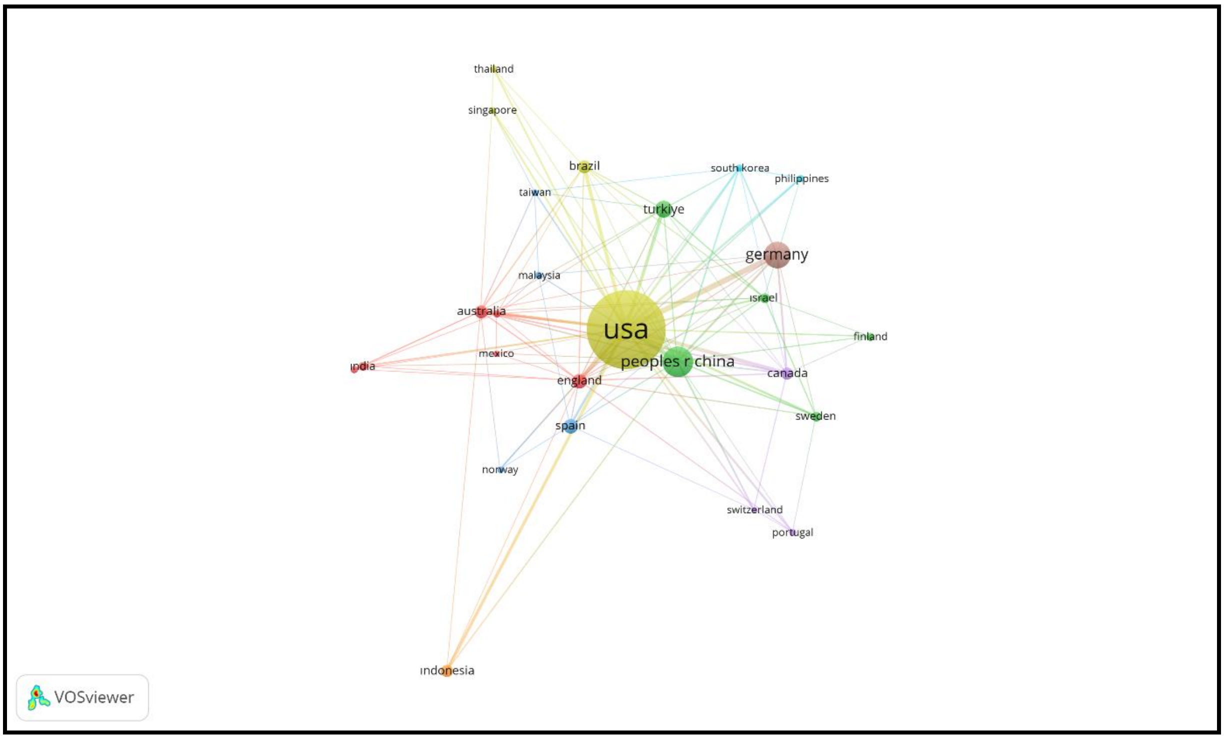

Figure 2. Global collaboration network by country

Figure 2 presents the citation analysis of countries contributing to scientific research on artificial intelligence in the field of chemistry education, based on data obtained from the Web of Science. When evaluated in terms of citation counts, the United States ranks first with 3,164 citations. It is followed by Germany with 392 citations and China with 388 citations. In terms of publication output, the United States again ranks first with 353 scientific publications. China holds the second position with 90 publications, while Germany ranks third with 74 publications. Considering total link strength, which reflects the extent of collaborative and citation relationships, the United States ranks first with a total link strength of 306. China follows with 84, and Germany ranks third with 78. These findings indicate that the United States maintains a leading position across citation impact, publication productivity, and collaborative network strength in this research area.

The United States stands out as one of the leading countries in the production of academic publications in the field of artificial intelligence and also ranks first in terms of citation counts among countries conducting research on artificial intelligence in chemistry education. This finding indicates not only a quantitative advantage in research output but also a high level of qualitative impact of the produced studies. China, Germany, and Turkey are among the other leading countries that follow the United States, making substantial contributions to the research in this field. Policies supporting the integration of technology into education, together with differences in research infrastructure and access to substantial funding sources, may help explain the observed rise in publication output across these countries (Arıcı, 2024; Ekin et al., 2025). The results clearly show that the United States exhibits the highest level of international collaboration, whereas the involvement of developing countries in these collaborative networks remains comparatively limited. In order to address this limitation, restructuring international collaboration networks in a more inclusive manner, deepening existing partnerships, and fostering new collaborations are considered critical requirements for both enhancing the diversity of knowledge production and strengthening global scientific capacity (Al-Marzouqi et al., 2024).

Most Influential Researchers Based on Citation Impact

Table 3 presents the geographical distribution of most influential researchers. A citation network map was constructed using a threshold of at least five publications and a minimum of one citation in order to identify citation relationships among authors. The analysis was performed based on 25 observation units, representing interconnected relationships within the author citation network.

Table 3. The most influential researchers based on citations

Rank	Author	Number of publications	Citation	TLS
1	M. Cooper	5	137	21
2	R. L. Stowe	8	126	37
3	R. Blonder	8	119	2
4	J. R. Raker	9	97	26
5	N. M. Becker	5	95	23
6	M. Stains	7	92	15
7	N. Graulich	10	91	25
8	G. V. Shultz	6	84	12
9	B. J. Yik	5	76	15
10	M. Popova	9	68	20

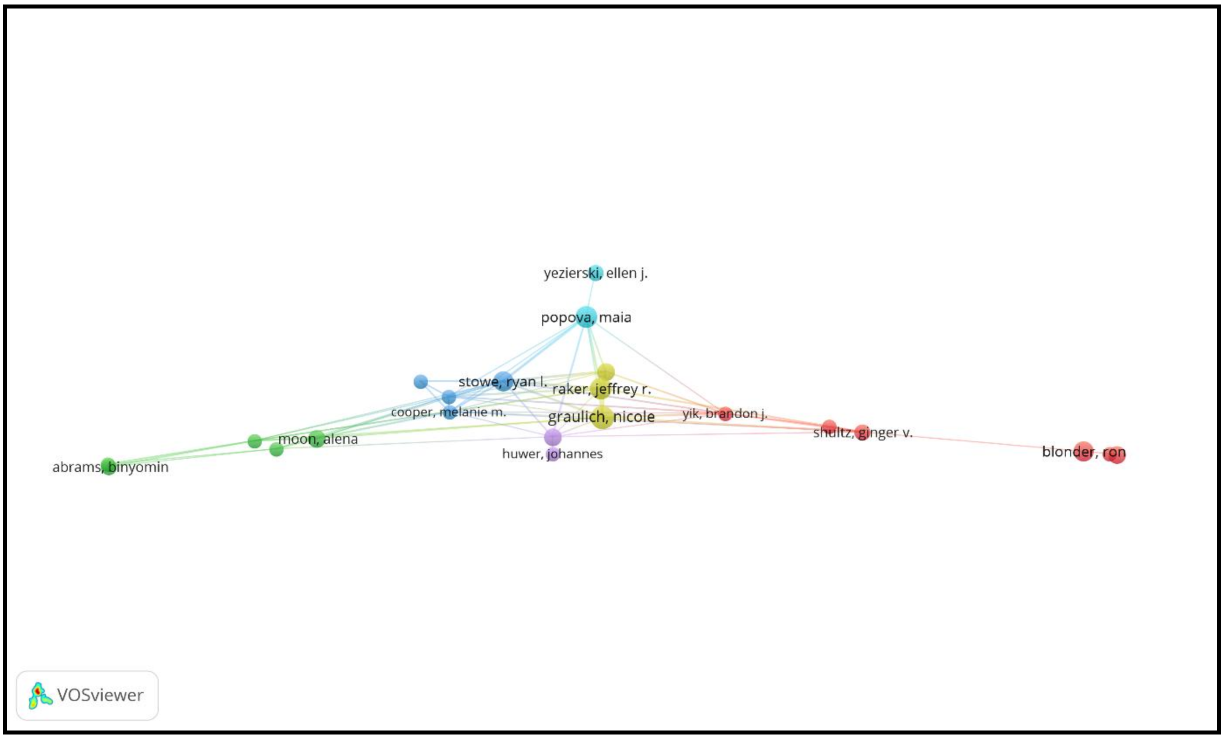

Figure 3. Author citation network

Figure 3 presents the citation analysis of authors contributing to scientific research on artificial intelligence in the field of chemistry education, based on data obtained from the Web of Science. When evaluated in terms of citation counts, M. Cooper ranks first with 137 citations. R. L. Stowe follows in second place with 126 citations, while R. Blonder ranks third with 119 citations. In terms of publication output, N. Graulich ranks first with 10 publications. J. R. Raker and M. Popova share the second and third positions, each with 9 publications. When considering total link strength, which indicates the extent of collaboration and citation relationships, R. L. Stowe ranks first with a total link strength of 37. J. R. Raker follows with 26, and N. Graulich ranks third with 25. These findings highlight the prominent authors in terms of citation impact, productivity, and collaborative influence within the field.

The analyzed data indicate that M. Cooper is one of the most prominent researchers cited in studies on artificial intelligence in chemistry education. In the study titled “Let Us Not Squander the Affordances of LLMs for the Sake of Expedience: Using Retrieval Augmented Generative AI Chatbots to Support and Evaluate Student Reasoning” (Cooper & Klymkowsky, 2024), the authors examine how large language models and generative AI applications can be utilized to support and assess student reasoning in chemistry education, thereby directly reflecting the current transformation in the field. The high citation impact of M. Cooper appears to stem not only from such directly AI-focused studies but also from earlier research addressing reasoning, conceptual understanding, and assessment processes in chemistry education (Houchlei et al., 2021; Noyes et al., 2022; Ralph et al., 2022). In addition, a study conducted by R. L. Stowe, who ranks second in terms of citation count (Stowe et al., 2021), demonstrates that the authors have made significant contributions to both the theoretical and practical foundations of AI-supported chemistry education research. In addition, a co-citation analysis was conducted in VOSviewer, with cited authors defined as the unit of analysis. To enhance the clarity of the visualization and reduce visual complexity, a threshold value of 33 was applied. The obtained results are presented in Table 4, while the corresponding network map is shown in Figure 4.

Table 4. The most influential researchers based on co-citation analysis

Rank	Author	Co-Citation	TLS
1	M. Cooper	233	1916
2	V. Talanquer	206	1470
3	K. S. Taber	185	878
4	A. H. Johnstone	152	866
5	J. K. Gilbert	109	608
6	M. Stieff	93	668
7	M. K. Seery	85	398
8	F. M. Watts	83	778
9	R. E. Mayer	80	433
10	A. Bandura	77	133

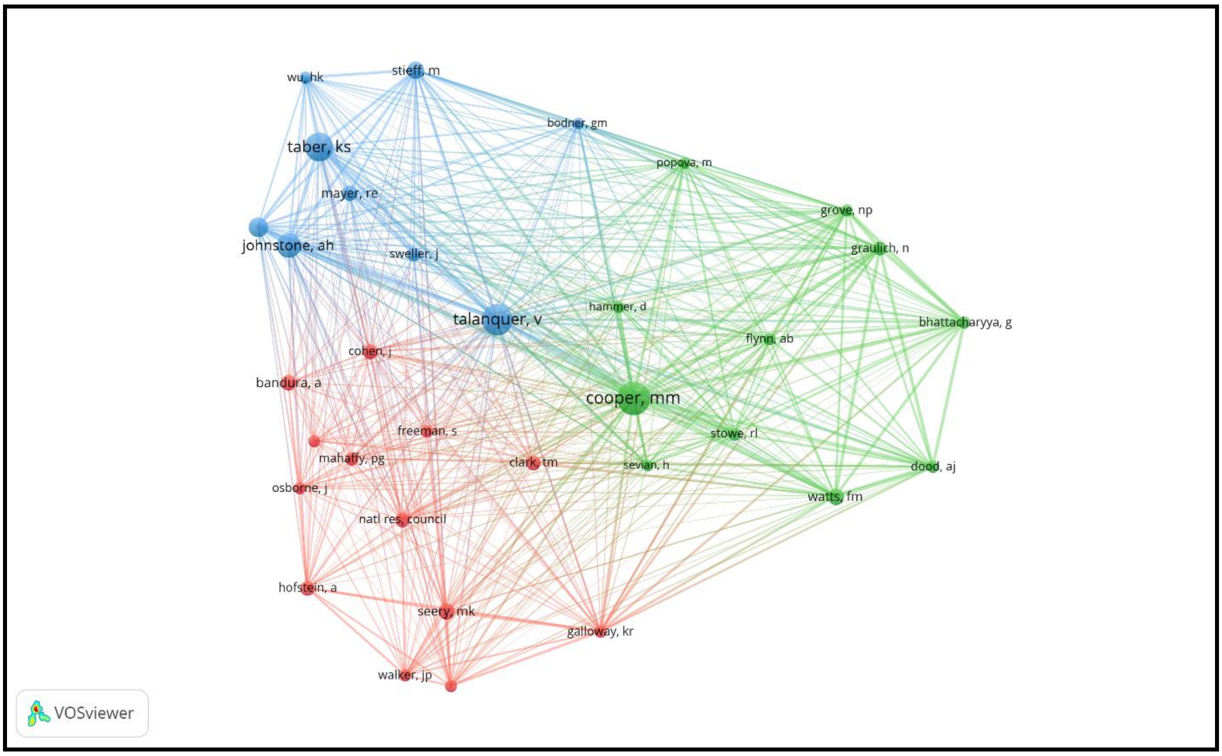

Figure 4. Co-author citation network

When Figure 4 is examined, it can be observed that the co-citation network consists of three distinct clusters, each represented by different colors. M. K. Seery is located at the center of the red cluster, M. Cooper occupies the central position in the green cluster, and V. Talanquer is positioned at the core of the blue cluster. M. Cooper (233 co-citations), V. Talanquer (206 co-citations), K. S. Taber (185 co-citations), A.H. Johnstone (152 co-citations) and J. K. Gilbert (109 co-citations) are highly cited authors. M. Cooper, with 233 co-citations and a total link strength (TLS) of 1916, stands out as the most central researcher in the field. The high co-citation value indicates that Cooper's work is frequently cited alongside other key sources in the literature, suggesting that these studies serve as foundational references within the research community. This finding demonstrates that M. Cooper's extensive body of work, spanning chemistry education, teaching strategies, learning assessment methods, and the integration of artificial intelligence in education, is widely recognized and heavily referenced by other scholars. Consequently, it can be concluded that Cooper holds a strong and influential position within the research networks shaping the development of the field.

The Most Influential Journals Based on Citation Counts

Journals with a minimum of three publications were considered in the analysis. A citation-based assessment was conducted to identify the most impactful journals within the field. The findings indicated that 33 of the 129 journals contributed at least three articles on the subject. Table 5 lists the ten journals identified as the most influential according to the analysis.

Table 5. The most influential journals

Rank	Journals	Number of publications	Citation	TLS
1	Journal of Chemical Education	451	3571	216
2	Chemistry Education Research and Practice	83	591	129
3	Education Sciences	37	189	20
4	Chemistry Teacher International	33	112	43
5	Frontiers in Education	32	148	9
6	International Journal of Science Education	24	102	16
7	Journal of Science Education and Technology	21	155	28
8	Education and Information Technologies	19	129	12
9	Journal of Baltic Science Education	19	54	4
10	Science & Education	14	59	25

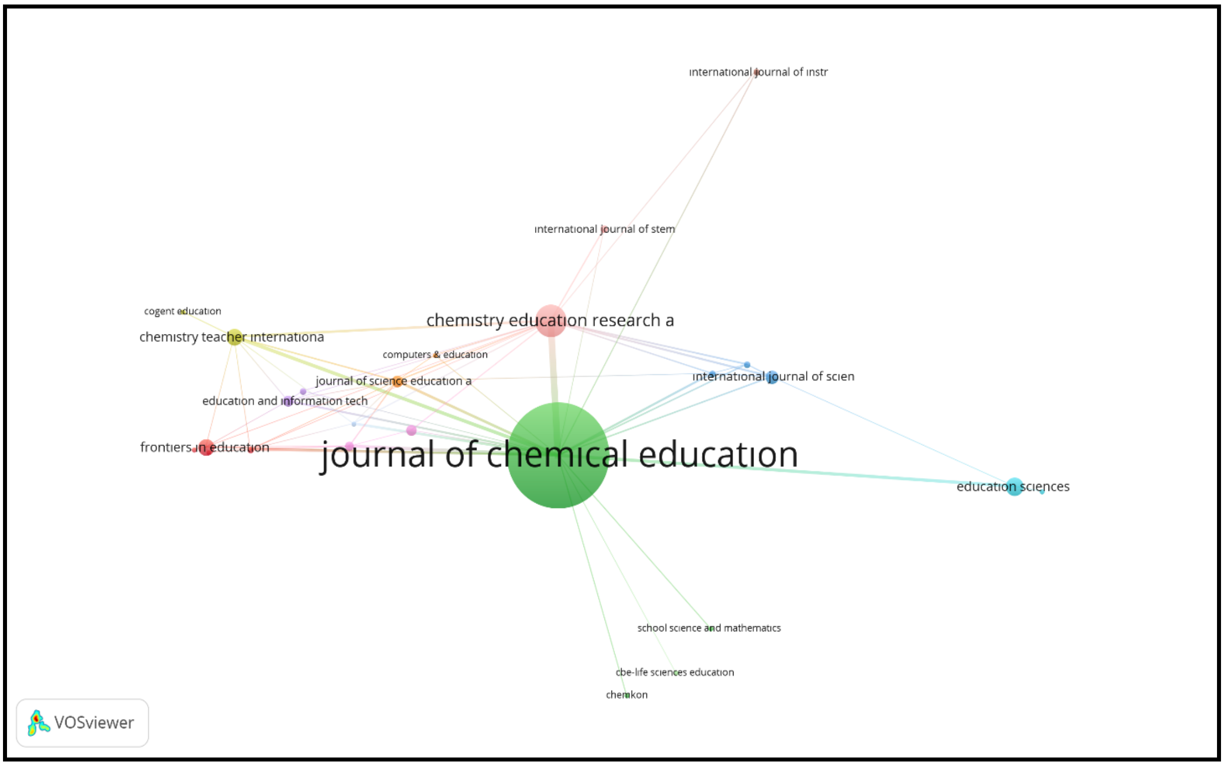

Figure 5. Journal network

Figure 5 presents the citation analysis of publication sources for scientific studies on artificial intelligence in chemistry education, based on data obtained from the Web of Science. When evaluated in terms of citation impact, the Journal of Chemical Education ranks first with 3,571 citations. It is followed by the Chemistry Education Research and Practice with 591 citations, and the Education Sciences with 189 citations. When the publication output of these sources is considered, the Journal of Chemical Education again holds the leading position with 451 publications. The Chemistry Education Research and Practice ranks second with 83 publications, while the Education Sciences ranks third with 37 publications. In terms of total link strength, which reflects the strength of collaboration and citation networks, the Journal of Chemical Education ranks first with a value of 216. It is followed by the Chemistry Education Research and Practice with 129, and the Chemistry Teacher International with 43. These results indicate that these journals, particularly Journal of Chemical Education, play a central role in disseminating research on artificial intelligence in chemistry education. The analysis of the data indicates that research on artificial intelligence in chemistry education is concentrated around a limited number of academic journals, which play a central role in both knowledge production and dissemination within the field (Journal of Chemical Education, Chemistry Education Research and Practice, Education Sciences and Chemistry Teacher International). In particular, the fact that the Journal of Chemical Education has by far the highest number of citations demonstrates that this journal is one of the most influential platforms in the field, not only in terms of publication output but also in terms of scholarly impact.

The Most Influential Universities Based on Citation Counts

Universities with at least six publications were included in the analysis. The findings indicated that 31 of the 1051 universities had produced six or more publications on the subject. Table 6 presents the ten most influential universities identified in the analysis.

Table 6. The most influential universities

Rank	Universities	Number of publications	Citation	TLS
1	University of South Florida	20	178	48
2	Michigan State University	14	272	34
3	University of Iowa	13	153	27
4	University of Helsinki	13	120	3
5	University of Wisconsin	11	165	45
6	University of Michigan	11	144	24
7	University of Georgia	11	169	9
8	University of Virginia	9	120	22
9	University of North Texas	9	52	19
10	University of Porto	8	54	5

Figure 6 presents the citation analysis of institutions and organizations contributing to scientific research on artificial intelligence in chemistry education, based on data obtained from the Web of Science. When evaluated in terms of publication output, the University of South Florida ranks first with 20 scientific publications. It is followed by Michigan State University with 14 publications. The University of Iowa and the University of Helsinki share the third position, each contributing 13 publications. In terms of citation impact, the Michigan State University ranks first with 272 citations. It is followed by the University of South Florida with 178 citations, and the University of Georgia with 169 citations. Regarding total link strength, which reflects the strength of collaborative and citation networks, the University of South Florida ranks first with a value of 48. It is followed by the University of Wisconsin with 45, while the Michigan State University ranks third with 34. These findings highlight the strong contribution of U.S.-based universities in shaping research on artificial intelligence in chemistry education.

The analysis of the data indicates that ranking institutions solely based on publication counts is insufficient, and that citation counts and impact levels should also be taken into consideration. The University of South Florida stands out as the most productive institution with 20 publications; however, its citation count (178) is relatively lower compared to some other universities, suggesting that productivity and impact do not always exhibit a linear relationship. In contrast, the Michigan State University, despite producing fewer publications (14), has achieved the highest impact with 272 citations, indicating that its studies have gained significant visibility and academic influence within the field. Overall, institutions such as Michigan State University and the University of Wisconsin stand out in terms of impact, whereas the University of South Florida leads in terms of productivity.

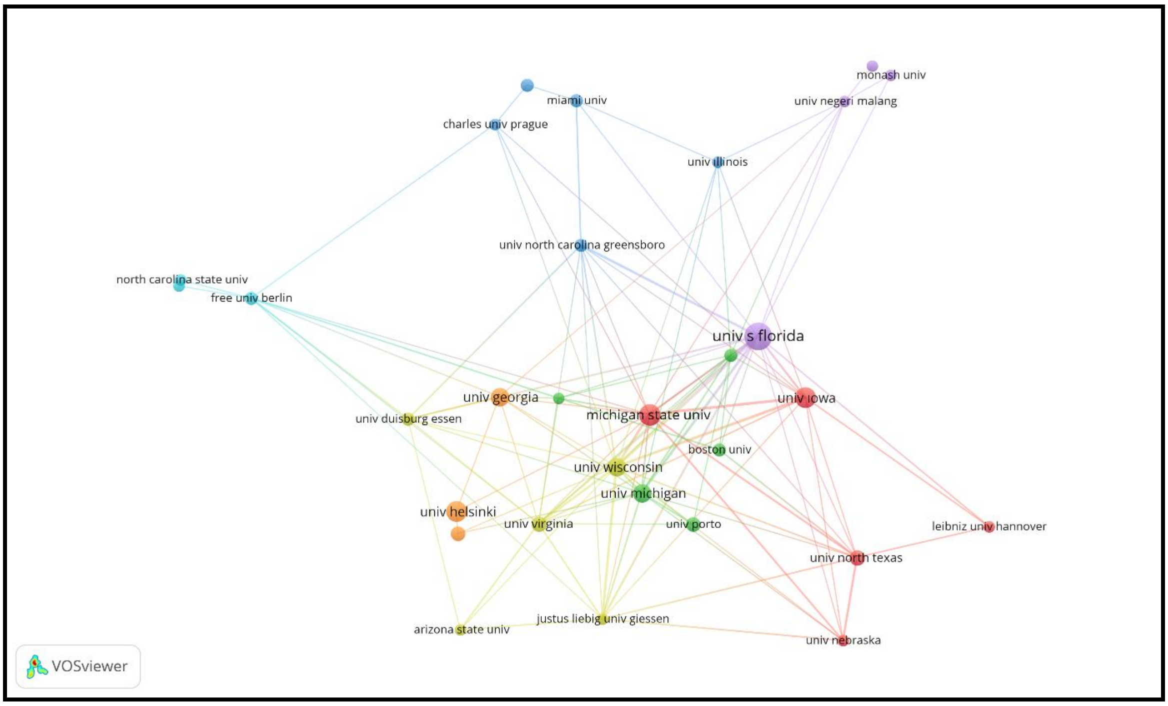

Figure 6. Universities network

Keyword Analysis

A total of 2179 keywords were identified across 972 publications related to artificial intelligence in chemistry education. In VOSviewer, the minimum occurrence threshold for keywords was set at 20. Following the analysis, 24 keywords met the inclusion criteria, forming 4 clusters with 213 links and a total link strength of 1585. Table 7 presents the ten most influential keywords identified in the study.

Table 7. The most influential keywords

Rank	Keyword	Occurrences	TLS
1	Undergraduate Education	225	541
2	Chemistry Education	173	281
3	General Chemistry	115	269
4	High School	105	179
5	Organic Chemistry	69	150
6	Assessment	66	173
7	Hands-on Learning	56	138
8	Graduate Education	53	153
9	Computer-Based Learning	52	155
10	Curriculum	47	132

Figure 7 shows that the most frequently recurring keyword is undergraduate education. The term undergraduate education, highlighted in red, appears 225 times as a keyword in the analyzed studies. The second most frequently used keyword is chemistry education, which appears 173 times. This is followed by general chemistry (115 occurrences), high school (105 occurrences), and organic chemistry (69 occurrences), respectively. These findings indicate that research on artificial intelligence in chemistry education is predominantly concentrated at the undergraduate level, while also extending to general chemistry contexts, secondary education settings, and specific subfields such as organic chemistry. As shown in Figure 7, the first red cluster contains nine keywords, the words analytical chemistry, computational chemistry, computer-based learning, graduate education, hands-on learning, laboratory instruction, organic chemistry, physical chemistry and undergraduate education. The second cluster, colored green, includes artificial intelligence, assessment, chemistry, chemistry education, curriculum, high school, professional development and science education. The words collaborative/cooperative learning, interdisciplinary/multidisciplinary, internet/web-based learning and student-centered learning are included in the blue cluster. The fourth cluster is yellow. The prominent keywords in this cluster are general chemistry, learning theories and problem solving.

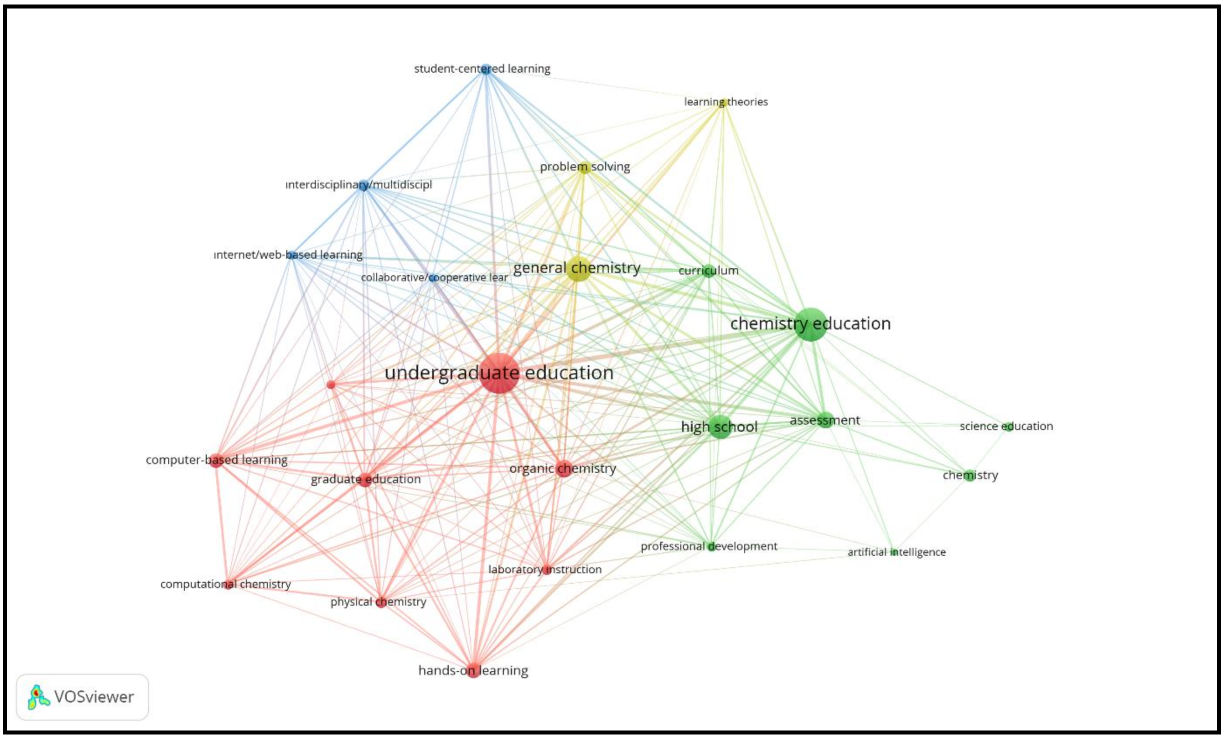

Figure 7. Keywords network

The results indicate that undergraduate education is the most prominent keyword, with 225 occurrences and a total link strength (TLS) of 541, representing the highest level of impact and connectivity. This finding suggests that the majority of artificial intelligence–focused studies are conducted within undergraduate chemistry education and that this theme forms a strong and well-established network across multiple studies (Erümit, 2025). Similarly, chemistry education appears as another significant keyword, with 173 occurrences and a TLS of 281. The relatively high link strength of this term indicates that the integration of artificial intelligence into chemistry education has been consistently explored within the literature. In particular, studies and critical reviews addressing applications such as laboratory simulations, virtual experiments, and instructional material development frequently emphasize this dimension (Buluş & Elmas, 2024; Erümit, 2025). Overall, these findings suggest that AI-based research in chemistry education is predominantly concentrated on enhancing undergraduate learning experiences, improving student performance, and personalizing instructional processes.

Conclusion

This bibliometric analysis shows that research on artificial intelligence in chemistry education has developed rapidly in recent years, with a clear acceleration in scientific output toward 2025. The field is becoming increasingly established, with contributions concentrated in a relatively small number of countries, institutions, authors, and journals that shape the overall research landscape. The results also indicate that literature is primarily focused on higher education contexts, particularly undergraduate chemistry learning, and is largely centered on foundational chemistry topics such as general chemistry. Moreover, the identified keyword patterns suggest that AI-related studies are mainly oriented toward teaching and learning processes rather than isolated technological applications. Overall, the study highlights that artificial intelligence has become an emerging and expanding research area within chemistry education. The growing connectivity among studies suggests that the field is moving toward a more integrated and mature structure, where future research is likely to diversify in both scope and application.

Recommendations

- Interdisciplinary studies that reveal the transformative potential of artificial intelligence use in chemistry education should be further supported.
- Strategies should be developed for the design and sustainability of learning environments in which human and artificial intelligence work effectively in collaboration.

- Research that provides concrete and applicable findings regarding the effective use of AI tools in chemistry education should be encouraged.
- Studies that address the use of generative artificial intelligence in teaching and learning processes in a more systematic and comprehensive manner should be increased.
- Innovative instructional models aimed at developing AI-supported personalized learning approaches should be designed and implemented.
- Activities and research projects based on human–AI collaboration should be integrated into educational environments.
- Interdisciplinary studies that reveal the transformative potential of artificial intelligence use in chemistry education should be further supported.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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