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Review Article

Artificial Intelligence in Intelligent Tutoring Systems for Education Literature Review and Bibliometric Analysis Using R-Biblioshiny

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Abstract: The rapid advancement of Artificial Intelligence (AI) has accelerated the integration of technology into digital learning, particularly through Intelligent Tutoring Systems (ITS) that are capable of adapting instructional content, feedback, and learning pathways to students' individual needs. The growing volume of publications on AI-based ITS highlights the need for a systematic mapping of the literature to better understand research trends, thematic emphases, and future research directions. This study aims to analyze publication trends, identify influential authors, institutions, journals, and countries, map the conceptual structure of the research field, and uncover research gaps and potential avenues for future studies. A quantitative approach was employed using bibliometric analysis. Data were retrieved from the Scopus database through searches of titles, abstracts, and keywords, and were subsequently screened using the PRISMA flow diagram, resulting in 322 articles published between 2012 and 2026. Bibliometric analysis was conducted using the Bibliometrix package and Biblioshiny to examine publication patterns, citation performance, collaboration networks, and keyword and thematic relationships. The findings indicate a steady increase in publications, with dominant themes centered on AI, intelligent tutoring systems, and adaptive learning. However, studies focusing on pedagogical implementation and long-term learning outcomes remain relatively limited. These results point to significant opportunities for future research, particularly in empirical evaluation and pedagogical integration. Overall, this study provides a comprehensive overview of the development of AI-based ITS research and serves as a valuable reference for researchers and practitioners in designing learning systems that align with educational needs.

Keywords: artificial intelligence, education, intelligent tutoring systems, literature review, r-biblioshiny

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INTRODUCTION

The advancement of Artificial Intelligence (AI) has driven a significant transformation in digital learning systems, particularly through the implementation of Intelligent Tutoring Systems (ITS) oriented toward adaptive and personalized learning. ITS are designed to tailor instructional content, strategies, and feedback based on learners' individual characteristics by continuously leveraging cognitive models and learning data, thereby contributing to improved educational effectiveness and sustainability (Lin et al., 2023; S. Wang et al., 2024). Recent literature mapping further indicates that ITS represent one of the most dominant AI applications in education due to their capacity to support personalization and data-driven decision-making processes (Fu et al., 2025).

The development of ITS has gradually expanded beyond a sole focus on cognitive aspects to include affective dimensions aimed at enhancing learner engagement and learning experiences. Affective Intelligent Tutoring Systems employ emotion recognition techniques to adapt interactions and instructional strategies; however, their implementation remains limited and requires validation across diverse educational contexts (Fernández-Herrero, 2024). Empirical studies and systematic reviews consistently demonstrate that AI-based ITS can enhance learning outcomes and student autonomy through personalized content delivery and adaptive feedback, including in educational settings with limited resources (Adayilo et al., 2025; Hidayat & Anggreini, 2025).

The integration of ITS with emerging technologies has further broadened the scope of AI applications in education. The incorporation of Augmented Reality (AR) and Virtual Reality (VR) into ITS facilitates more immersive and contextualized learning environments, thereby supporting experiential learning and active interaction (Lampropoulos, 2025). Recent developments also indicate that AI technologies are increasingly embedded within ITS to enable more dialogic tutor-learner interactions, provide rapid feedback, and simulate instructional support through step-by-step guidance, conceptual explanations, and problem-solving scaffolding. Nevertheless, these applications remain largely in developmental and exploratory stages, and their pedagogical effectiveness as well as real-world implementation require further empirical evaluation (Lai & Lin, 2025; Marquez-Carpintero et al., 2026).

The growing volume of publications related to AI and ITS necessitates analytical approaches capable of comprehensively mapping research trends, dominant themes, and scientific collaboration patterns. Scopus-based bibliometric analysis has proven effective in revealing the intellectual structure and developmental trajectories of AI research in education, including studies on ITS (Irwanto, 2025). Scoping studies also emphasize the importance of data-driven literature mapping to support sustainable digital education transformation and

to clarify the role of ITS in improving student retention and academic success in higher education contexts (Saltos et al., 2025).

Despite the substantial potential of AI-based ITS, systematic investigations highlight persistent challenges related to ethics, data privacy, algorithmic bias, and disparities in implementation across educational contexts. Long-term evaluations of the pedagogical impacts of ITS remain limited, underscoring the need for comprehensive analyses to better understand the practical and conceptual implications of intelligent tutoring system adoption (Létourneau et al., 2025). Recent reviews further note that the integration of chatbots and generative AI tools within ITS may enhance learning efficiency; however, such integration requires well-defined pedagogical frameworks to ensure that learners' reflective and critical engagement is not diminished (Elnaffar et al., 2026).

This study aims to contribute to a deeper understanding of how Artificial Intelligence has been applied and developed within Intelligent Tutoring Systems in educational contexts. The findings are expected to identify key challenges and future research opportunities, while providing relevant insights for researchers, educators, and developers of AI-based intelligent learning systems. Based on these objectives, this study is guided by four main research aims, namely:
RO1: To analyze publication trends in Artificial Intelligence-based Intelligent Tutoring Systems in education using Scopus data.
RO2: To identify influential authors, journals, institutions, and countries in AI-based Intelligent Tutoring Systems research.
RO3: To analyze the conceptual structure of AI-based Intelligent Tutoring Systems research through keyword co-occurrence and thematic mapping.
RO4: To identify research gaps and future directions in the development and application of AI-based Intelligent Tutoring Systems.

THEORETICAL FRAMEWORK

Artificial Intelligence in Intelligent Tutoring Systems

Artificial Intelligence (AI) in Intelligent Tutoring Systems (ITS) is employed to support learning processes that are more closely aligned with the individual needs of learners. ITS operate by analyzing students' learning activities, such as their responses to tasks and recurring error patterns, and subsequently adapting the instructional content and feedback provided. These systems are designed to deliver individualized learning guidance, moving away from uniform instructional approaches toward more personalized learning experiences. This approach distinguishes ITS from conventional digital learning systems, as it enables continuous adjustment of instructional strategies based on data-driven insights and learners' ongoing learning progress (Villegas-Ch et al., 2025).

The development of AI-based ITS is supported by advances in technologies such as machine learning, knowledge modeling, and natural language processing. These technologies allow the system to continuously update its understanding of students' competencies as learning unfolds. In addition, ITS are increasingly applied to offer more flexible learning pathways, timely feedback, and targeted instructional support. Empirical evidence suggests that AI-based ITS are effective across various structured learning domains and hold considerable potential for enhancing student engagement and learning experiences, including by accounting for motivational factors and learning context (Latif et al., 2026; Romano et al., 2025; Son, 2024).

Trends in Intelligent Tutoring Systems Research

Recent research on Artificial Intelligence-based Intelligent Tutoring Systems has demonstrated an increasingly clear trajectory toward personalized and adaptive learning. Intelligent tutoring systems no longer function merely as platforms for content delivery; rather, they are being developed to understand learners' individual needs and learning progress. Sabeima et al. (2022) highlight personalization as a central focus in the development of ITS, particularly through the adaptation of learning materials, instructional sequencing, and feedback based on students' profiles and interaction patterns. The application of AI further enables tutoring systems to monitor learning processes continuously and to adjust instructional strategies in response to learners' behaviors, as evidenced by the study of (Gligorea et al., 2023).

Current research directions also emphasize student modeling and learning data analysis as key components in the advancement of ITS. Ma et al. (2025) underscores that representing learners' learning states through learner models forms the foundation for intelligent tutors in determining appropriate instructional interventions. This approach is further strengthened by the use of learning analytics to evaluate instructional effectiveness and to support pedagogical decision-making, as discussed by Böck et al. (2025). Pelánek. (2025) adds that, despite significant progress in AI-based ITS, recent studies increasingly stress the importance of balancing system sophistication with user interpretability, ensuring that learning processes remain transparent and manageable for learners

METHODS

Bibliometric Analysis Using Biblioshiny

Bibliometric analysis is a quantitative approach used to analyze and map the development of scholarly literature within a particular field of study. This approach enables researchers to identify publication patterns, author productivity, research collaboration networks, and the conceptual structure of a research domain based on publication metadata. In the context of technology-enhanced education research, bibliometric analysis has been widely employed to systematically and data-drivenly examine research trajectories and knowledge dynamics (Lim & Kumar, 2024; Mondal, 2025).

In this study, bibliometric analysis was applied to explore and examine research trends related to Artificial Intelligence in Intelligent Tutoring Systems (ITS) within the educational domain. This approach was selected because it provides a comprehensive overview of publication growth, dominant research themes, and inter-topic relationships that collectively shape the research landscape of AI-based ITS in education. The analysis was conducted using the Bibliometric package through the Biblioshiny interface in R. The analytical procedures included performance analysis (annual scientific production, citation analysis, and most relevant authors, sources, affiliations, and countries) and science mapping techniques such as co-authorship analysis, keyword co-occurrence analysis, thematic mapping, and conceptual structure analysis.

Study Design

This study was designed as a quantitative investigation employing bibliometric analysis. The method was chosen for its ability to handle large volumes of scientific publications and to generate both quantitative and visual interpretations of research data. The analysis focused

on publication metadata, including year of publication, authorship, institutional affiliations, countries of origin, and research keywords, enabling an objective and structured mapping of research developments (Donthu et al., 2021; Lim & Kumar, 2024).

The research focus was directed toward mapping the evolution of studies on Artificial Intelligence in Intelligent Tutoring Systems within the educational field over a predefined time period. This quantitative approach facilitated the identification of research trends, patterns of scientific collaboration, and emerging core themes in the literature, thereby providing a comprehensive understanding of the research dynamics in this area (Mondal, 2025). The publication period was limited to 2012-2026 to capture the contemporary development phase of AI integration in educational technologies. Although the search timeframe began in 2012, no publications meeting the inclusion criteria were identified for that year; therefore, the final dataset effectively covered studies published between 2013 and 2026.

Search Strategy (PRISMA)

This study aimed to identify research trends related to Artificial Intelligence in Intelligent Tutoring Systems in educational contexts. The literature search strategy followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a transparent and systematic article selection process (Rethlefsen & Page, 2022). The search was conducted using the Scopus database, yielding an initial set of 426 records without restrictions on publication year or language.

The search was conducted in the Title, Abstract, and Keywords fields of the Scopus database using the following Boolean query: TITLE-ABS-KEY ("artificial intelligence" OR "AI") AND ("intelligent tutoring system*" OR "ITS") AND (education OR educational OR learning OR "educational technology"). The initial search yielded 426 records, which were subsequently screened according to predefined inclusion criteria limiting the publication period to 2012–2026 and restricting the language to English. Although the timeframe began in 2012, no eligible publications were identified for that year; thus, the final dataset effectively comprised studies published between 2013 and 2026. After completing the screening process, 322 articles were retained for bibliometric analysis, and the detailed article selection procedure is presented in **Figure 1**.

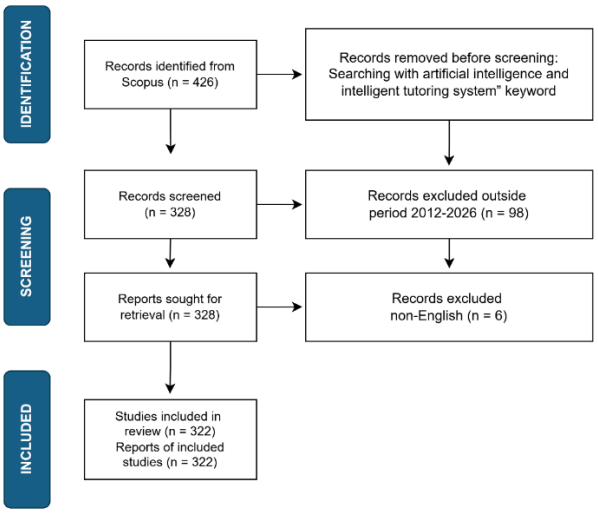


Figure 1. PRISMA flow of article selection Source: Scopus Database

Data Collection

Data were collected by retrieving scholarly articles indexed in the Scopus database. The search was focused on the Title, Abstract, and Keywords fields to identify publications directly related to the topic of Artificial Intelligence in Intelligent Tutoring Systems within educational contexts. The search was conducted in January 2026, with the document type limited to journal articles. All retrieved records were exported from Scopus in CSV format and served as the initial research dataset. The initial search yielded 426 articles. This dataset was subsequently filtered according to the publication period of 2012-2026. The next stage of screening involved the removal of non-English articles through a manual review of titles and abstracts, resulting in 322 articles that met the inclusion criteria.

The inclusion criteria comprised peer-reviewed journal articles indexed in Scopus, published between 2012 and 2026, written in English, and explicitly addressing Artificial Intelligence in Intelligent Tutoring Systems within educational contexts. Exclusion criteria included publications outside the specified period, non-English articles, and documents not directly relevant to the research focus. The final dataset of 322 articles was then analyzed using the Bibliometrix package through the Biblioshiny interface to systematically map publication trends, patterns of scientific collaboration, and the conceptual structure of the research field based on data-driven analysis (Büyükkidik, 2022; Nowakowska, 2025). The data processing and analysis workflow is presented in **Figure 2**.

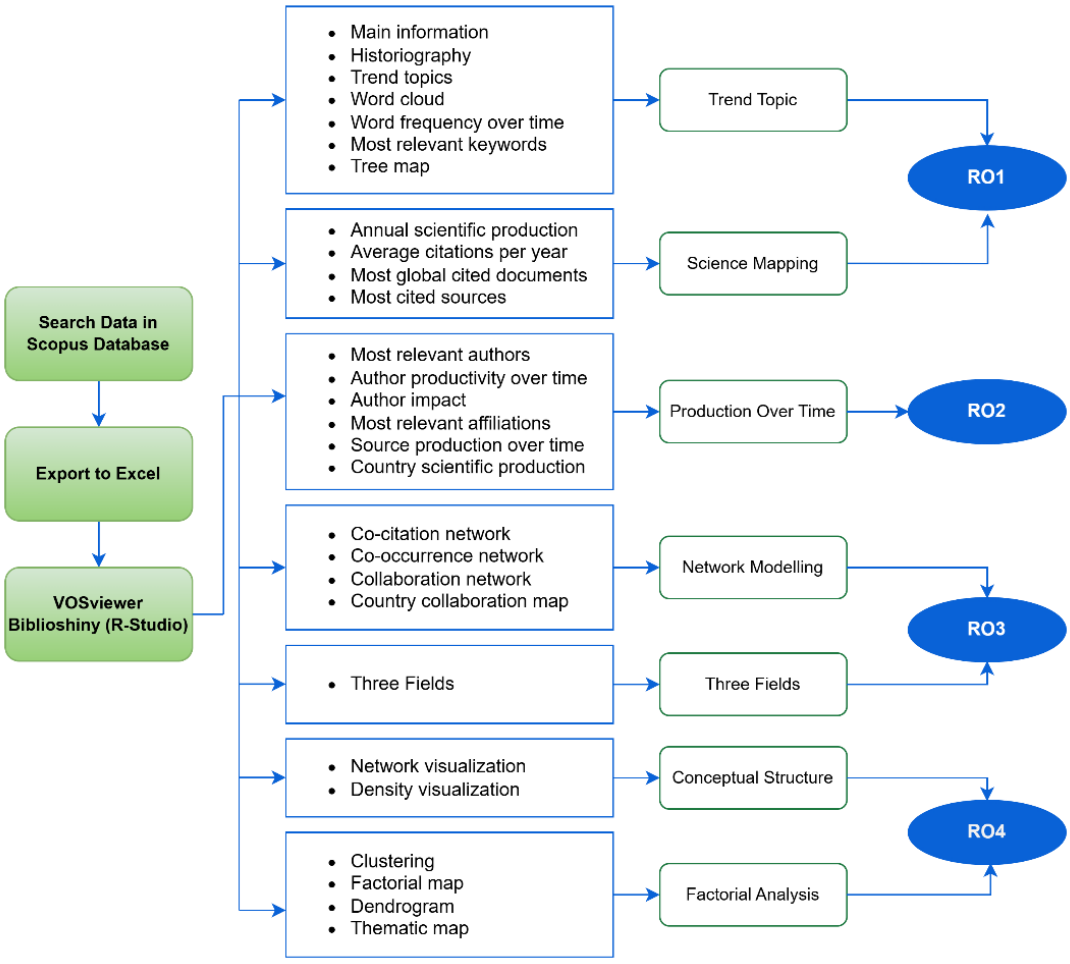


Figure 2. Research Analysis Workflow and Mapping Techniques

RESULT

Main Information

The dataset analyzed in this study, along with an overview of its characteristics, is presented in **Figure 3.**

Figure 3. Summary of The Research Data Source: Scopus Database

This visualization presents bibliometric data illustrating the relationships between research articles and authors in the field of Artificial Intelligence in Intelligent Tutoring Systems for education. Each node represents an individual article, while the connections between nodes indicate patterns of co-citation, co-occurrence, and collaboration. The graph provides an overview of the bibliometric characteristics of the dataset, highlighting the relationships among articles and authors in AI-based ITS research. Additionally, an analysis of topic trends was conducted to gain insights into the direction of research development.

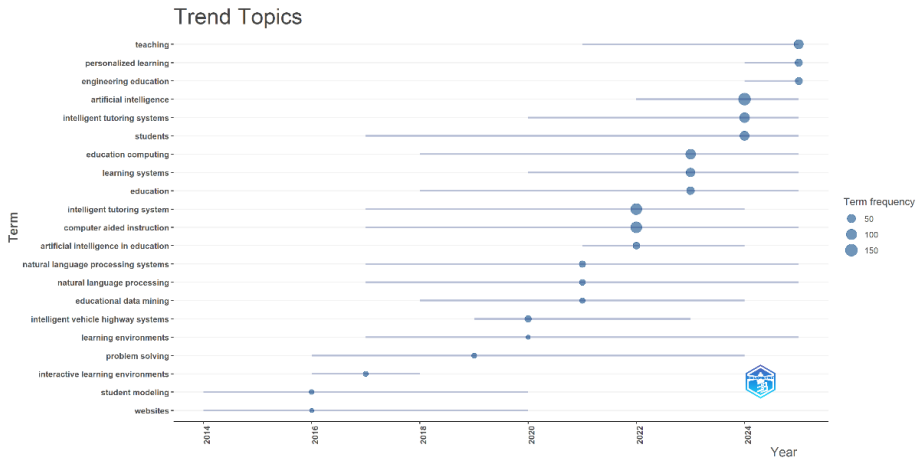


Figure 4. Topic Trends Artificial Intelligence in Education Source: Scopus Database

The visualization in Figure 4 illustrates the dynamics of research topics over the observation period. Terms such as artificial intelligence, intelligent tutoring systems, educational computing, learning systems, and computer-aided instruction exhibited the highest frequencies and appeared consistently from the mid to late period. Early topics, including websites and student modeling, were more prominent in the initial phase, followed by an expansion of themes toward the integration of AI and intelligent tutoring systems. More recent terms, such as personalized learning, natural language processing, and educational data mining, emerged in the latest period, albeit with relatively lower frequencies compared to the other dominant themes.

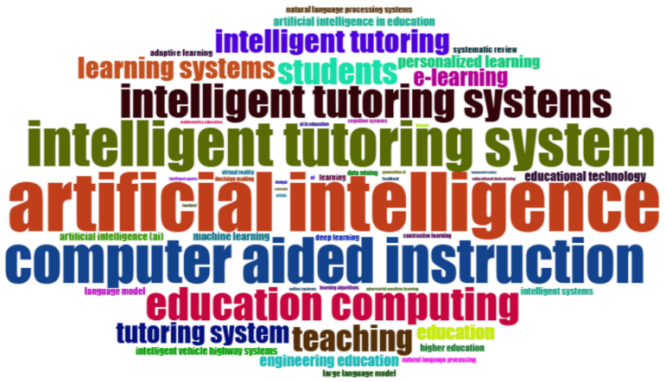


Figure 5. Word Cloud of Keywords AI In Education Source: Scopus Database

The word cloud visualization in Figure 5 displays the most frequently occurring terms in the literature. Terms such as artificial intelligence, intelligent tutoring system(s), computer-aided instruction, and educational computing are the most prominent, highlighting the central role of AI and computer-assisted tutoring systems in the research. Other terms, including learning systems, students, teaching, and personalized learning, appear in smaller sizes, representing supporting themes that link technological aspects with educational contexts. This visualization underscores the dominance of artificial intelligence, intelligent tutoring system(s), and computer-aided instruction within the analyzed literature.

Science Mapping

Science mapping is a bibliometric approach used to visualize the structure and development of a research field based on publication and citation relationships, enabling the identification of trends and knowledge growth dynamics over a given period (Chen et al., 2023; Pessin et al., 2022). This analysis utilizes data on annual scientific production and average citations to depict the intensity of publications and the scholarly impact of the published articles.

Annual scientific production shows a year-on-year increase, particularly from 2021 to 2025. The highest number of publications was recorded in 2025, whereas the earlier years exhibited relatively lower output. Average citations per article tended to be higher in earlier years and decreased in the most recent period, reflecting differences in citation accumulation over time. A summary of annual scientific production and average citations per article is presented in **Table 1**.

Table 1. Annual Scientific Production and Average Citations per Article Source: Scopus Database

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Number of Article	6	9	6	11	11	4	7	11	13	15	32	68	123	6
Average Citations per Article	68.67	91.00	51.00	122.64	42.18	26.75	39.43	78.09	59.00	63.93	86.84	17.29	3.15	0.00

Global citation analysis identified the most highly cited publication as Crompton (2023), published in International Journal of Educational Technology in Higher Education, with 923 citations. This was followed by Roll (2016) in International Journal of Artificial Intelligence in Education and Kamalov (2023) in Sustainability. Local citation analysis indicated that Baker

(2016), published in International Journal of Artificial Intelligence in Education, received the highest number of local citations, followed by Chu (2022) in Australasian Journal of Educational Technology and Chen (2022) in Educational Technology & Society. These findings highlight the strong influence of these publications within the analyzed research network, despite differences in their global citation counts.

Production Over Time

By Affiliation

Affiliation analysis indicated that The Education University of Hong Kong was the most productive institution, contributing eight articles, followed by Central China Normal University and the School of Computer Science, each with seven publications. Other institutions, including Beijing Normal University, University of Patras, and Université Moulay Ismaïl, demonstrated consistent contributions with six articles each.

By Author

Chen X emerged as the most influential author based on the highest H-index and citation counts since 2022. Other authors, such as Hu X and Xie H, showed consistent contributions, while Alyüz N and Aslan S represented emerging authors with increasing productivity. Overall, author productivity patterns conform to Lotka's Law, wherein a small proportion of authors account for the majority of publications.

By Source

The International Journal of Artificial Intelligence in Education was the dominant publication source, with 34 articles, followed by Education and Information Technologies and IEEE Access. This indicates that research in this field is concentrated in a few key journals.

By Country

Based on data from 2013 to 2025 (Figure 6), the United States exhibited the highest publication output with a consistent upward trend throughout the observation period. China and India experienced significant growth, particularly after 2020, with a sharp increase in the number of articles. Germany and Canada showed lower publication levels relative to other countries but maintained a relatively stable growth pattern over time.

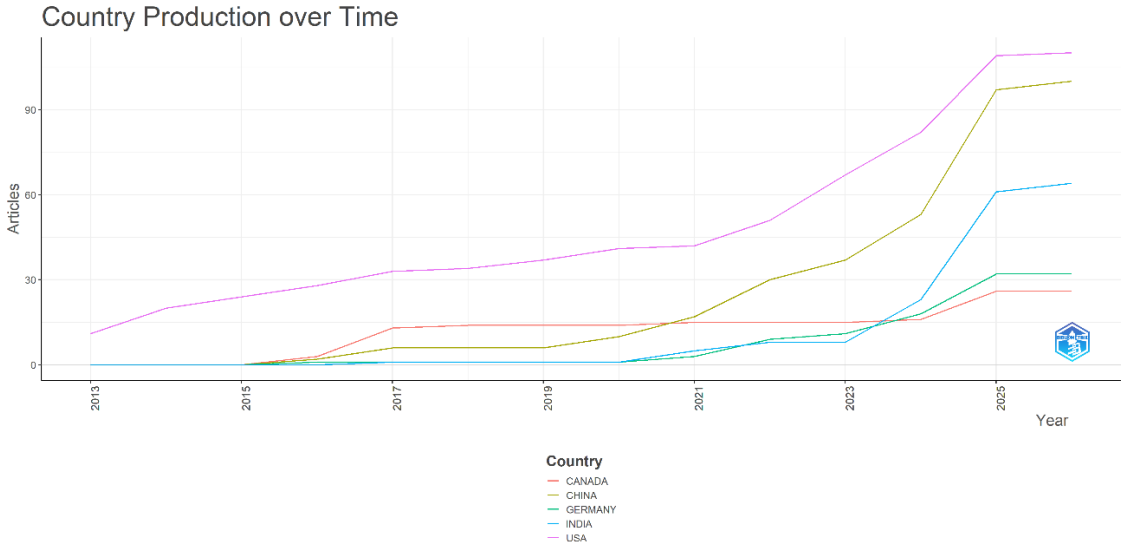


Figure 6. Country Production Over Time Source: Scopus Database

The global scientific production map in Figure 7 shows that countries shaded in dark blue exhibit high scientific contributions, predominantly the United States, China, and India. Countries in Europe, Southeast Asia, and South America are generally depicted in lighter shades, indicating lower publication output. This distribution reflects variations in the number of publications across countries during the study period.

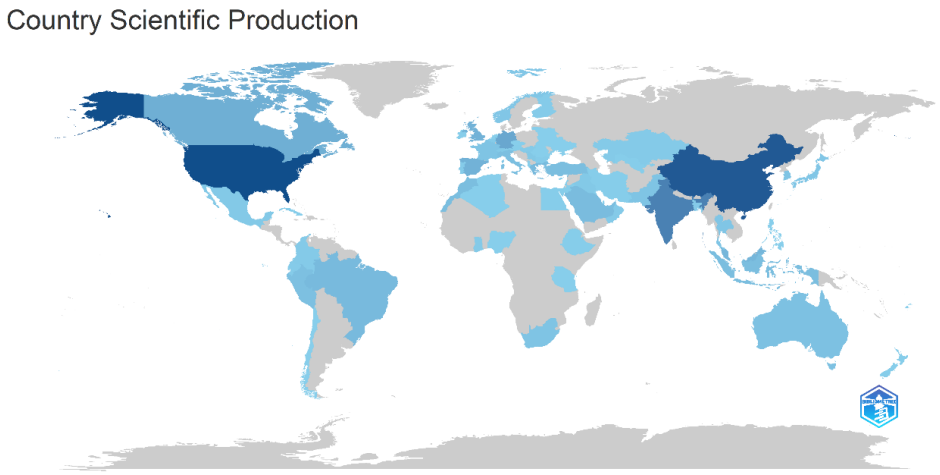


Figure 7. Country Collaboration Map Source: Scopus Database

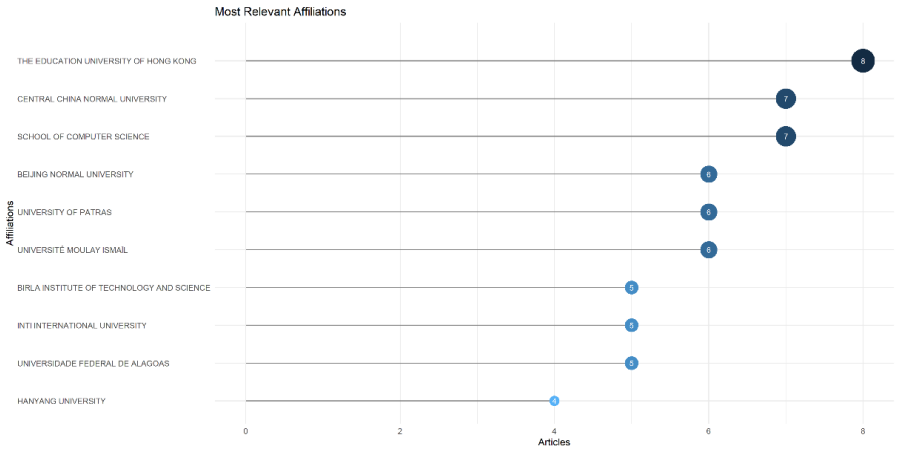


Figure 8. Most Relevant Affiliations Source: Scopus Database

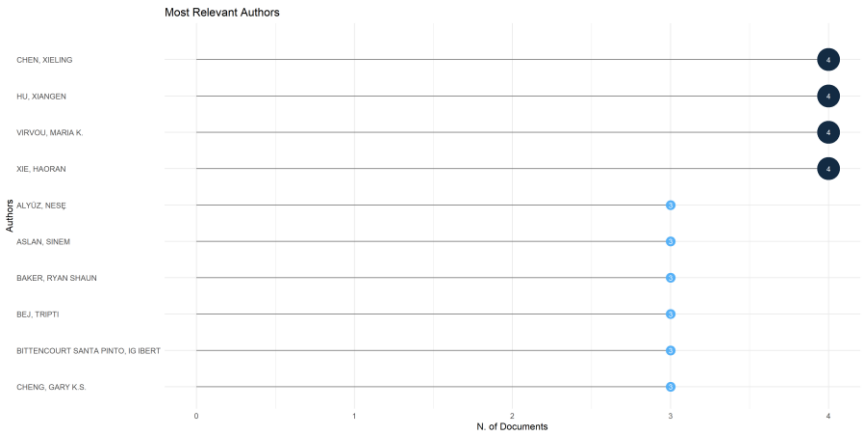


Figure 9. Most Relevant Authors Source: Scopus Database

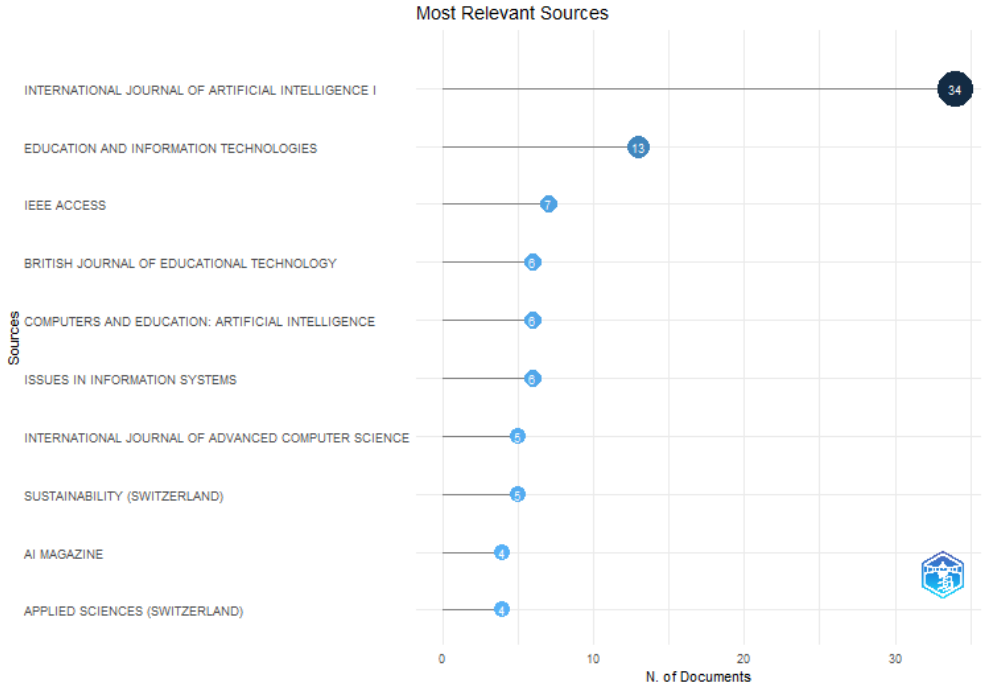
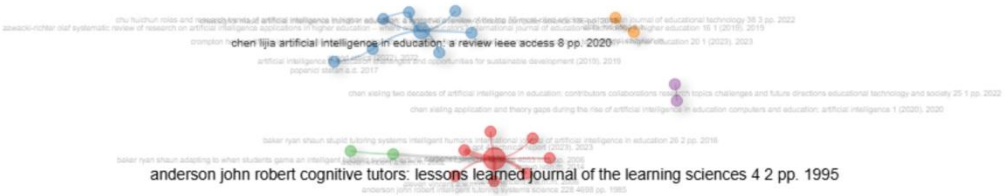


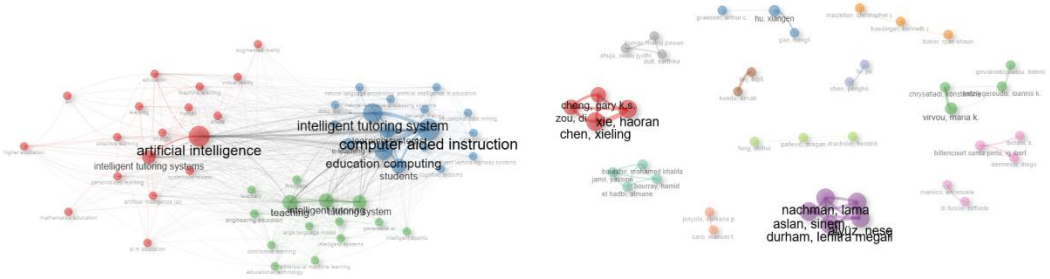
Figure 10. Most Relevant Sources Source: Scopus Database

Network Modeling

Network modeling in bibliometrics encompasses co-citation, co-occurrence, and collaboration networks, which are utilized to analyze relationships between publications, citation patterns, co-occurrence of words or authors, and collaboration patterns between researchers or institutions (Klarin, 2024; Marzi et al., 2025; Öztürk et al., 2024). This approach provides an understanding of the structure and dynamics of scientific communication within a field of research.



(a)



(b) (c)

Figure 11. (a) Co-citation Network; (b) Co-occurrence Network; (c) Collaboration Network Source: Scopus Database.

The co-citation, co-occurrence, and collaboration networks in the image demonstrate the interrelationships between references, keywords, and research actors in the field under study. The utilization of nodes and color-coded clusters serves to illustrate the grouping of dominant themes and research communities, thereby facilitating the identification of the primary focus of the research. The node size represents the level of influence or frequency of occurrence, while the line thickness indicates the strength of citation, co-occurrence, and collaboration relationships. This visualization offers a succinct and lucid depiction of the intellectual framework and patterns of research interaction.

Three-Field

The three-field diagram (Figure 12) is a tool employed in bibliometric analysis to visually represent the relationship between research keywords, the country of origin of publications, and journal sources. This visualization illustrates the distribution and interconnection of specific research topics with contributing countries and journals. Consequently, it aids in the identification of research focus patterns and publication directions within a field of study (AVŞAR & PELİT, 2025; Haruna et al., 2024). This diagram offers a succinct representation of the interrelationships between pivotal elements in scientific literature, derived from bibliographic data.

The analysis indicates that core keywords such as artificial intelligence and intelligent tutoring systems demonstrate larger node sizes and denser link structures, suggesting a strong concentration of publications across specific countries and specialized journals. In contrast, pedagogical keywords such as students, teaching, and educational technology appear with relatively smaller nodes and weaker interconnections. This pattern reflects a thematic concentration in AI-driven ITS research while indicating comparatively limited cross-field integration with broader educational perspectives.

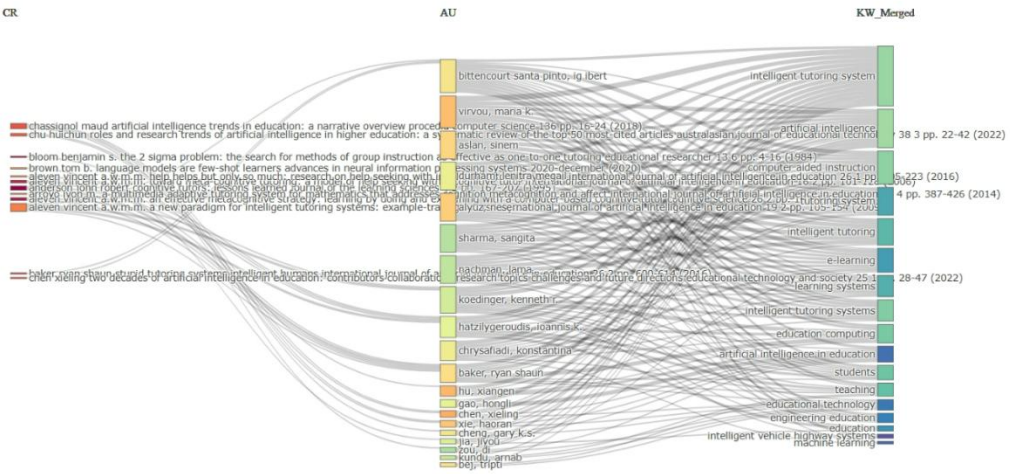
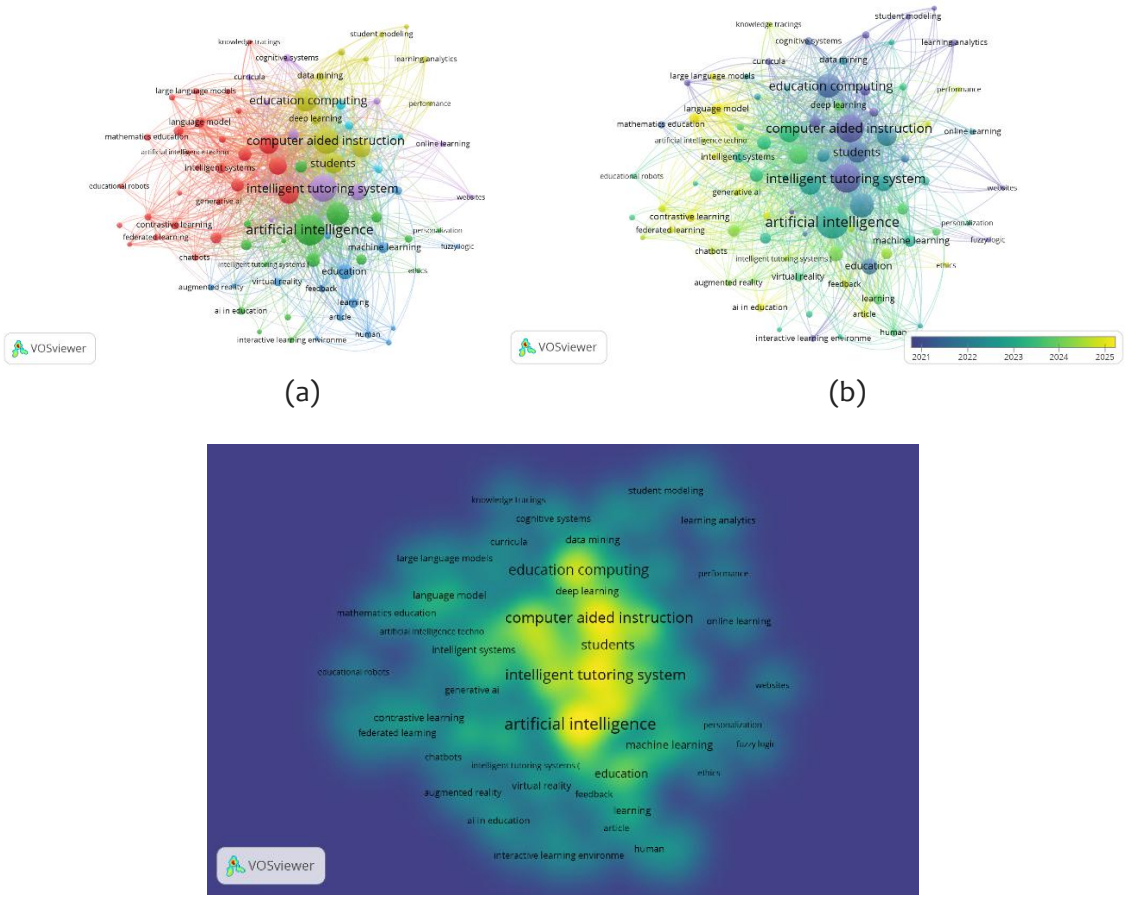


Figure 12. Three-Field Plot Showing Relationships Among Authors, Keywords, and Countries
Source: Scopus Database

Conceptual Framework

Co-occurrence network maps are employed to delineate the conceptual framework of a research domain, with the interrelationships between keywords in scientific publications serving as the underlying data (Aria & Cuccurullo, 2017; Donthu et al., 2021). This method demonstrates the interconnectedness of terms in the literature, thereby forming thematic clusters that represent the research focus in the field under study (Figure 13).



(a) (b)

(c)

Figure 13. (a) Network Visualization; (b) Overlay Visualization; (c) Density Visualization
Source: Scopus Database

Network visualization, overlay, and density visualization demonstrate the structure and dynamics of research themes, where large nodes such as artificial intelligence, intelligent tutoring systems, computer-aided instruction, and students represent the primary focus with a high level of interconnection between concepts. The connecting lines reflect the strength of keyword co-occurrence relationships, while the overlay visualization shows the temporal development of topics, with more recent occurrences of terms such as machine learning and deep learning indicating the current direction of research. The density visualization corroborates the predominance of research on artificial intelligence and intelligent tutoring systems, while other concepts manifest with reduced intensity.

Conceptual Structure

The conceptual structure is employed to comprehend the relationships between pivotal concepts in a given field of research, with the basis of the co-occurrence of keywords in scientific literature. This analysis is instrumental in identifying patterns and groupings of conceptual themes that constitute the knowledge structure in the field under study (Öztürk et al., 2024). The results of the conceptual structure analysis are presented in the form of a factorial map in **Figure 14**.

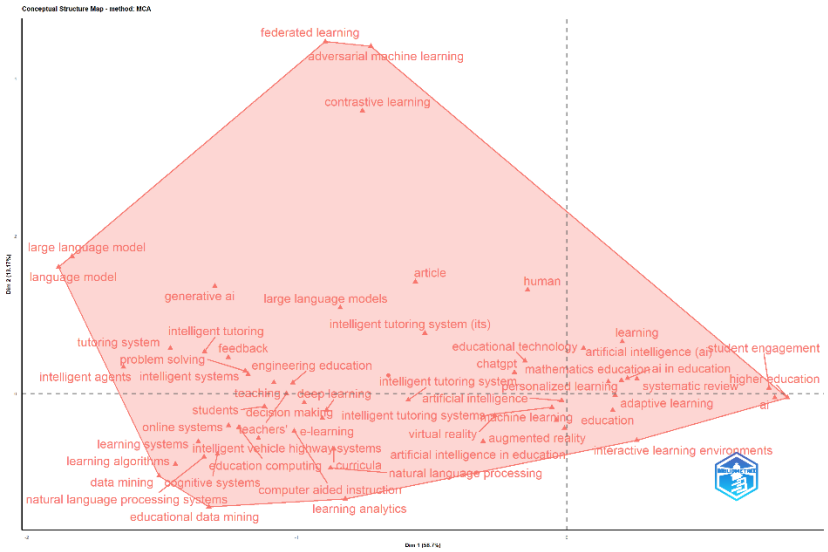


Figure 14. Factorial Map Source: Scopus Database

Figure 14 presents a factorial map-based conceptual structure map, which illustrates the interrelationships between concepts based on their co-occurrence. Concepts such as artificial intelligence, intelligent tutoring systems (ITS), education, and artificial intelligence in education are located in the center area as core themes that connect various topics. The left area is dominated by technical and computational approaches, such as natural language processing, machine learning, learning analytics, data mining, large language models, and deep learning. In contrast, the right area reflects the context of educational application, including student engagement, adaptive learning, personalized learning, and learning environments. This distribution indicates a transition in research focus from technology development to pedagogical implementation in learning practices.

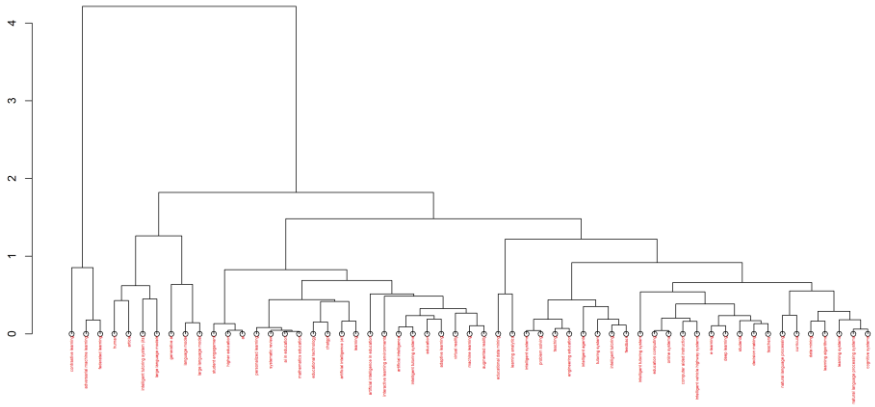


Figure 15. Dendogram Source: Scopus Database

As illustrated in Figure 15, a dendrogram is employed to demonstrate the grouping of research concepts according to their level of similarity. Concepts situated on the same branch or in close proximity exhibit a closer relationship, while those on disparate branches demonstrate more pronounced thematic differences. This visualization methodically reveals the pattern of concept grouping, thereby establishing a foundation for subsequent analysis in Figure 16 through the utilization of a thematic map.

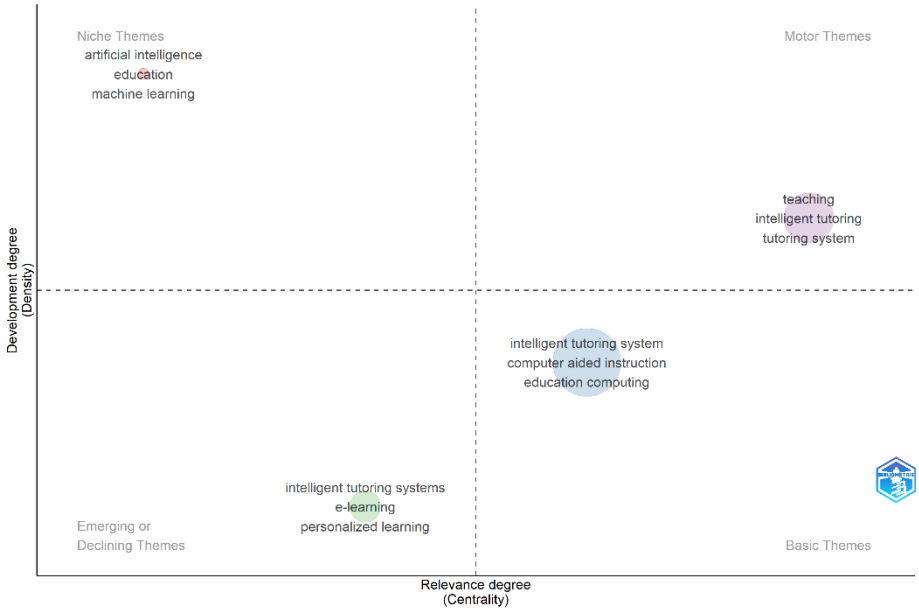


Figure 16. Thematic Map Source: Scopus Database

A thematic map (Figure 16) illustrates the distribution of research themes according to centrality and density. The upper right quadrant is characterized by a preponderance of major themes, including teaching, intelligent tutoring, and tutoring systems, which exhibit a high degree of relevance and development. The lower right quadrant encompasses fundamental themes, including computer-aided instruction and education computing as the foundational element of research. The upper left quadrant indicates themes such as artificial intelligence, education, and machine learning, while the lower left quadrant exhibits themes that are in a state of development or decline, including e-learning and personalized learning.

DISCUSSION

RO 1: To analyze publication trends in Artificial Intelligence-based Intelligent Tutoring Systems in education using Scopus data

A meticulous examination of annual scientific output reveals a persistent growth trend in research pertaining to intelligent tutoring systems founded on artificial intelligence since 2013. The number of publications increased gradually in the early period, then exhibited a more pronounced increase after 2020 until recent years. This pattern is indicative of the mounting academic interest in the application of AI in educational settings, as well as a surge in research endeavors exploring the development of intelligent and adaptive learning systems.

This growth trend aligns with the findings of several bibliometric studies, which indicate that research on artificial intelligence (AI) in education has seen an increase in publication frequency and diversification of research themes from year to year. This trend is consistent with the advancement of computing technology and the integration of digital solutions in learning practices (Akhmadieva et al., 2024; Irwanto, 2025; A. Nguyen et al., 2023). These results suggest that AI-based ITS topics are garnering increased attention within the domain of educational technology research. Furthermore, this trend indicates a persistent growth in the field, attracting the interest of researchers across various disciplines.

RO 2: To identify influential authors, journals, institutions, and countries in AI-based Intelligent Tutoring Systems research

The results of the author productivity analysis demonstrate that research on Artificial Intelligence-based Intelligent Tutoring Systems (AI-based ITS) has been developed by a number of relatively active researchers who contribute continuously. A number of authors, including Chen X, Hu X, and Sharma S, have been documented as having the highest number of publications in the collection of articles that have been analyzed. This finding suggests the presence of a core group of researchers who play an important role in maintaining continuity and accumulating knowledge in the field of AI-based ITS. The observed pattern of dominance among productive authors aligns with the broader characteristics of bibliometric studies, which demonstrate that a limited number of researchers often contribute disproportionately to the advancement of a particular field of study (Donthu et al., 2021). The utilization of Bibliometrix instruments facilitates the methodical and structured identification of author productivity (Aria & Cuccurullo, 2017). The affiliation of prominent authors, which is predominantly comprised of universities and research institutions, substantiates the pivotal role of academic institutions in fostering research sustainability.

The distribution of publication sources indicates a concentration of AI-based ITS articles in a number of journals that focus on educational technology and artificial intelligence. The International Journal of Artificial Intelligence in Education has the highest number of publications, followed by Education and Information Technologies and IEEE Access. The preponderance of publications in these thematic journals underscores the pivotal role of reputable journals as the predominant medium for shaping and disseminating scientific discourse related to AI-based ITS. The observed pattern of concentration in specific journals aligns with earlier bibliometric findings, which indicate that field-specific journals play a pivotal role in shaping the development and focus of AI research in the field of education (Akhmadieva et al., 2024).

A preliminary investigation of geographical distribution reveals that the United States, China, and India are the countries with the largest publication contributions. The preponderance of these countries in the field of artificial intelligence and digital learning systems is indicative of their robust research capacity, substantial funding support, and advanced technological infrastructure. The observed pattern of publication concentration in countries with well-established research ecosystems aligns with the findings of prior studies, which indicate that the productivity of research in the field of educational technology tends to be concentrated in global research centers (Irwanto, 2025; T. T. K. Nguyen et al., 2023). A comprehensive analysis of the extant literature reveals the prominent roles of authors, journals, institutions, and countries in shaping the research landscape of AI-based intelligent tutoring systems.

RO 3: To analyze the conceptual structure of AI-based Intelligent Tutoring Systems research through keyword co-occurrence and thematic mapping

Keyword co-occurrence analysis is employed to delineate the conceptual structure of research on Artificial Intelligence-based Intelligent Tutoring Systems and to identify the interrelationships between major themes developing in this field. This approach facilitates

the grouping of keywords into multiple thematic clusters, thereby providing a comprehensive representation of the research's direction and focus.

Table 2. Content Analysis by Cluster

Aspect	Cluster 1	Cluster 2	Cluster 3
Focus	This cluster represents the core conceptual foundation of research on artificial intelligence in intelligent tutoring systems, emphasizing artificial intelligence, intelligent tutoring systems, machine learning, adaptive learning, and AI in education. These keywords show high centrality and strong interconnections, indicating their central role in shaping the field.	This cluster focuses on technical and system-oriented aspects of AI-based educational systems, including computer aided instruction, education computing, learning systems, data mining, deep learning, and natural language processing. The cluster reflects research efforts directed toward system architecture, computational methods, and data-driven learning processes.	This cluster highlights pedagogical and implementation-oriented themes, such as teaching, tutoring systems, educational technology, feedback, and instructional practices. The emphasis is placed on how intelligent tutoring systems are applied within real learning and teaching contexts.
Thematic Position	Based on the thematic map, this cluster corresponds to basic and motor themes, reflecting well-established and mature topics that function as both the foundation and driving force of research on AI-based intelligent tutoring systems.	This cluster is positioned as a motor theme, indicating technically mature and influential topics that support the development, optimization, and scalability of intelligent tutoring systems.	This cluster aligns with applied and emerging pedagogical themes, showing a stronger orientation toward instructional implementation rather than core system development.
Similarities	The cluster shares artificial intelligence concepts with Cluster 2 and provides the conceptual basis for educational applications examined in Cluster 3.	The cluster overlaps with Cluster 1 through shared AI techniques and connects with Cluster 3 through their use in instructional and learning systems.	The cluster is linked to Clusters 1 and 2 through the application of AI technologies, while shifting the emphasis toward teaching and learning practices.
Differences	The cluster emphasizes foundational concepts and general AI applications in education rather than detailed	The cluster prioritizes computational models, system design, and data-driven approaches	The cluster differs by focusing on instructional practices, teacher-system interaction, and

	system design or classroom-level implementation.	more strongly than conceptual or pedagogical discussions.	learning processes rather than core AI algorithms or system architecture.

The cluster structure depicted in Table 2 indicates that research in the domain of AI-based ITS is founded on a relatively well-established conceptual foundation, which is further solidified by ongoing technical advancements. The core cluster functions as a foundational framework that maintains the continuity of the research direction, while the technical dimension plays a role in driving the development and optimization of the system through computational and data-based approaches. The pivotal function of data analytics in fostering the adaptability of learning systems has been a subject of discussion in the study by Wang et al. (2022). Chrysafiadi et al. (2023) demonstrate that the utilization of data empowers tutoring systems to offer more contextual and customized instructional responses.

The pedagogical orientation reflected in other clusters indicates a heightened focus on the implementation of Information Technology in learning practices. The scope of research has broadened from system development to its application in supporting the learning and teaching process in real-world contexts. This approach of integrating technology with instructional strategies is documented in the study by Wu & Yang. (2022), while Rahman et al. (2024) underscore the significance of congruence between educational technology innovations and pedagogical needs. This pattern indicates that the development of AI-based ITS is directed towards a more balanced integration of conceptual, technical, and pedagogical aspects.

RO 4: To identify research gaps and future directions in the development and application of AI-based Intelligent Tutoring Systems

Compared to previous bibliometric studies that broadly examined artificial intelligence in education, this study provides a more focused analysis of AI-based Intelligent Tutoring Systems by integrating trend analysis, influential contributors, and thematic structures. This approach allows a clearer identification of underexplored pedagogical dimensions within ITS research. The results of the bibliometric and thematic analyses indicate that AI-based ITS research remains predominantly oriented toward system development and technical optimization, including algorithms, adaptive models, and system architecture. Although prior studies have highlighted the rapid growth of AI applications in education, the present findings reveal a notable imbalance between technically oriented themes and pedagogically grounded research.

A number of studies have demonstrated the considerable potential of artificial intelligence-based intelligent tutoring systems in facilitating personalized learning. However, empirical validation of pedagogical effectiveness in real institutional contexts remains limited (Prayuda et al., 2025) and implementation challenges continue to be reported (Lachheb et al., 2025). A conspicuous absence of integration of pedagogical, ethical, and social context aspects in ITS development has been identified, indicating a significant research gap in this area. A significant number of studies have placed a greater emphasis on the technical performance of the system rather than on the learning experience of students, the role of teachers, and the transparency of AI-based decision-making processes. This pattern reflects a structural

imbalance between technological advancement and pedagogical integration within ITS research. Abulibdeh. (2025) underscores the significance of user-centered design in ensuring the relevance and ease of application of the system in learning practices. Turmuzi & Tyaningsih. (2025) underscore the significance of instructional design and learning evaluation as pivotal components in the development of ITS.

In order to effectively map the direction of ITS research based on AI, it is imperative to take into consideration the methodological limitations inherent to this field of study. The utilization of a singular database, such as Scopus, might not encompass all pertinent publications, particularly those from conference proceedings and regional journals. A multi-database approach, in conjunction with a combination of analysis techniques, is a prevalent methodology in bibliometric studies, as it facilitates the attainment of a more comprehensive coverage of the extant literature. A similar approach is observed in the field of AI mapping research in education, where the integration of diverse data sources is employed to enhance the comprehensiveness of the analysis (Irwanto, 2025). Additionally, citation-based metrics are subject to time-lag bias and may not fully reflect the empirical rigor of recent studies. To that end, further research is recommended to integrate technical reinforcement, long-term empirical evaluation, and pedagogical considerations so that the development of AI-based ITS is more in line with educational needs.

CONCLUSION

This study utilizes bibliometric mapping to present an analysis of the development of Artificial Intelligence research in Intelligent Tutoring Systems within the educational field. The results of the analysis demonstrate relatively consistent growth in publications and an increasingly defined research theme structure, with core themes such as artificial intelligence, intelligent tutoring systems, and adaptive learning dominating as the conceptual foundation. The primary focus of the study remains oriented towards enhancing technical and computational facets, while the integration of pedagogical dimensions and contextual implementation is progressively garnering attention within the extant literature. This pattern indicates opportunities for leveraging AI-based ITS to support learning personalization, system efficiency, and the use of data in learning decision-making.

The novel methodological approach of this research utilizes bibliometric analysis to map the intellectual structure, collaboration networks, and research theme dynamics using Biblioshiny. This mapping can serve as a preliminary reference for researchers, providing a foundation for understanding the landscape of AI-based ITS research. The analysis identifies several areas that require further development, including long-term empirical evaluation, integration of pedagogical and human-centered AI approaches, and the use of a single database in literature collection. It is recommended that further research be conducted in order to empirically test the impact of learning, strengthen multidisciplinary collaboration, and develop ITS designs that are more aligned with educational practice needs.

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