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EVOLVING EDUCATIONAL TECHNOLOGIES: A BIBLIOMETRIC STUDY ON AI IN INTELLIGENT TUTORING SYSTEMS

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ABSTRACT

A metamorphic advancement has been made in the field of educational technology with the integration of Artificial Intelligence (AI) and Intelligent Tutoring Systems (ITS). This integration equips a tailored and robust learning gest. This paper uses an inclusive bibliometric analysis to examine the convergence of ITS and AI, focusing on the Scopus database for gathering bibliographic data. The procedure is designed over the PRISMA flow chart, which accurately deals with the inclusion and exclusion criteria for the literature review. This study utilizes advanced bibliometric tools such as Biblioshiny, VOSviewer, and CiteSpace, providing a multifaceted view of the field's development and impact. The analysis yields significant insights into various aspects: the annual scientific production in the field, identifying the most influential authors, and discerning the most relevant sources. Furthermore, it highlights the most globally cited documents, pinpoints the most productive country in this research area, and delves into the trending topics. Additionally, the study incorporates a thematic map, factorial analysis, bibliographic coupling of documents, and the co-occurrence of all keywords, providing a multidimensional view of the field. The analysis categorizes keywords with prominent citation bursts, studies the co-citation of cited authors, and engages network visualization techniques for cited journals. A timeline visualization of international collaborations suggests further acumens into the global subtleties of the field. The paper concludes by finding appropriate research gaps and discussing the application of these findings, thus contributing to further research in the field of educational technology.

Keywords: *Intelligent Tutoring System, Artificial Intelligence, Bibliometric Analysis, Biblioshiny, VOSviewer, Citespace*

1. INTRODUCTION

Intelligent Tutoring Systems (ITSs) use AI technology for their work and are meant to give tailored training and responses to users without any human intervention (1,2). Intelligent Tutoring Systems (ITS) and Artificial Intelligence (AI) are bonded together to give a pivotal upgrade to the field of educational technology, giving custom-made and adapting adaptive learning exposure (3). AI employs Natural Language Processing (NLP) and adaptive learning algorithms to enhance its work in finding (4). The scenario is like this, ITS works with the knowledge seekers in a very engaging and resourceful manner. ITS can be used in numerous situations across several educational situations, from primary-level institutions to professional courses, taking into consideration varied learning requirements mostly useful in the special education sector (5). According to the changing educational environment, ITS provides lifelong learning and professional development (6). Machine learning is used by ITS for its advancements in technologies, which envisions learner performance and develops learning trails, and data analytics helps in deepening the understanding of learning patterns (7). More recent technologies like Augmented and Virtual reality are also employed in ITS to create a

fantastic learning experience for the users (8). The impact made by AI and ITS in the education sector is enormous, shelving out personalised learning services, improved engagement for the users, and the ability to control learners worldwide regardless of any barriers, be it geographical or socio-economic. With the advancement of technology, ITS will surge ahead to more sophistication, thereby changing the structure of the educational field for more active learning.

ITS uses data analysis to unceasingly improve the instructional material and the approaches (9). The regular update and improvement of the educational strategies and learning content, helped by the use of AI, makes sure that the learning experience of a user is effective and significant (10). The effect of ITS can be seen not just in the educational sector but also in areas like professional development and corporate training. The capability to provide personalized and assessable educational content makes ITS invaluable, especially in situations where the users find it hard to access quality education and training (11). All said, there are daunting challenges when it comes to the implementation of ITS, like guaranteeing the impartiality and transparency of the AI algorithms, upholding the privacy and security of user data, and incorporating these structures efficiently within the prevailing educational contexts (3). More cutting-edge technologies like natural language understanding and improved adaptation mechanisms will be incorporated with ITS as advancement in technology continues to take place. This transformation of the educational scenario makes personalized learning more effective and accessible for a larger group of learners.

A bibliometric analysis of the integration of Intelligent Tutoring Systems and Artificial Intelligence comprises a thorough study of the prevailing literature to distinguish the key facts, themes, and major contributors in the field. By utilizing tools like Biblioshiny, VOSviewer, and CiteSpace, researchers can conduct comprehensive analyses of scientific publications and patents in these domains (12–14). The scrutiny stage checks into trends in publication, analyzing the progress and degeneration in research attention over time, and engages citation analysis to identify pivotal works and important researchers (15–17). The thematic analysis then comprehends gaps in the research and forecasts trends shortly, conferring a modern insight (18–20). An essential part of this synthesis is evaluating the didactic and wider societal impression, with policy and ethical consequences of ITS and AI incorporation. Visualization tools like VOSviewer or CiteSpace are employed to show data in an available format, such as citation networks and keyword maps, supplemented by a descriptive analysis that concisely abridges the crucial findings and inferences. This synthesis gives an overall view of the research scenario in the case of ITS and AI, which further is a chance for practitioners and policymakers to generate and delve into future research and its application.

Biblioshiny, which provides a more collaborative and user-friendly interface for doing bibliometric analyses, is an innovative platform for the R package 'bibliometrix' (21–23). A researcher void of in-depth knowledge in programming can use this software to identify trends, perform in-depth analysis, and visualize data. VOSviewer focuses on creating and picturising bibliometric networks like keyword co-occurrence, co-citation and co-authorship (24–26). It is extensively used for its capacity to instinctively map and comprehend the intricate relationships and organisations within the scientific literature. CiteSpace, which focuses on understanding valuable points in the evolvement of a research area, is based on Java software and is used for synthesising and picturing patterns and trends in scientific literature (13,27,28). This particular application is very much appreciated for its capability to disclose evolving trends, essential publications, and significant authors, majorly by way of clustering techniques and co-citation analysis.

The following are the research objectives of the study:

- Systematic mapping of the research on integration of Intelligent Tutoring System and AI
- Analysis of trends and patterns in the literature, including the evolution of research themes over time.
- Flawlessly identifying key authors, articles, and influential works in the field.

- Effectively exploring collaboration networks among authors and institutions.
- Detecting emerging themes and gaps in the literature.
- Providing recommendations for future research.

2. LITERATURE REVIEW

Badaracco and Martínez (2011) emphasize the style of ITS for competency-based education. They suggest a model that streamlines the intricacy integral to generic ITS. Their method participates in an investigative procedure to make the arrangements more understandable and controllable, thereby taking up the challenges of using ITS across several educational spheres (29). Ivanova (2021) analyzes the application of ontologies in the progress of knowledge mockups for ITS. She showcases an approach for generating low-cost ITS with reusable parts and cataloging of tutoring tactics. Her study is noteworthy for its insistence on cost-effectiveness and dynamic approach selection in ITS expansion (10). Virvou and Sidiropoulos (2013) tried to get hold of the incorporation of ITS with social networking stands, explicitly for mathematics teaching. They tackle how children's acquaintance with the internet and such technology can be used to improve e-learning situations. This study emphasizes the probability of joining social networking with ITS for tailored and cooperative learning practices (30). Lippert et al.'s (2020) study moves into conversational ITS using manifold agents. They deliberate how multi-agent arrangements can model perfect behaviors and social communications, ranging beyond the competencies of single-agent systems. This study highlights the pedagogical profits of several agents in ITS, showing developments in technology and educational approaches (31). Huang and Chen (2016) studied the architecture of internet-based ITS, synthesizing its structural configuration and main technologies. They stress the status of numerous models, such as reasoning student models and learning direction reasoning models, in generating more smart tutoring systems. Their study is decisive for comprehending the technical characteristics and effectiveness of web-based ITS (32). Yu and Wang (2014) researched about the significant technologies in numerous agent-based ITS. Their paper concentrates on tackling the boundaries of traditional network training systems by including multi-agent systems. This study is crucial in comprehending how ITS can pretend to be real teaching surroundings and support sovereign and collaborative learning (33).

3. MATERIALS AND METHODS USED

For this study, Scopus was chosen as the primary bibliographical data source since it covers a wider range of quality journals than other databases (34–36). We used the keywords "Intelligent Tutoring Systems" and "Artificial Intelligence" to retrieve publications, and there were no language restrictions. We only considered journal articles, conference papers, and book chapters. In total, we collected 1283 documents from 493 different sources between 1984 and 2024. To select papers for bibliometric analysis, we followed the PRISMA approach, which is a three-phase procedure. In the first phase, we identified and extracted the data for analysis from the databases. In the second phase, we excluded Reviews, Editorials, Books, Short Notes, Erratum, and Surveys, including only Articles, Conference papers, and Book chapters. We stored our findings as "CSV" and RIS files and performed bibliometric analysis using CiteSpace version 6.2.R3 (Advanced) and Bibloshiny software. Table 1 summarizes the main aspects of this investigation. Figure 1 illustrates the PRISMA approach used in selecting papers for bibliometric analysis.

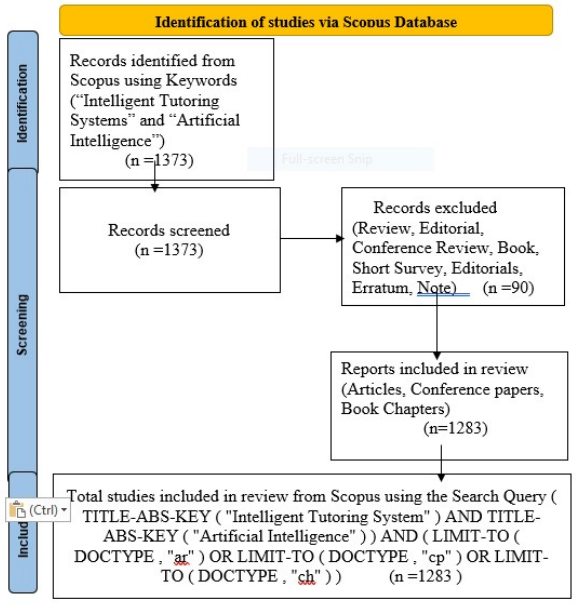

Figure 1: PRISMA Flow diagram used to Identify, Screen and Include papers in the Bibliomertic Analysis.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1984:2024
Sources (Journals, Books, etc)	493
Documents	1283
Annual Growth Rate %	1.75
Document Average Age	13.2
Average citations per doc	12.51
References	26838
DOCUMENT CONTENTS	
Keywords Plus (ID)	4845
Author's Keywords (DE)	2032
AUTHORS	
Authors	2819
Authors of single-authored docs	176
AUTHORS COLLABORATION	
Single-authored docs	193
Co-Authors per Doc	3.18
International co-authorships %	11.93
DOCUMENT TYPES	
Article	363
Book chapter	39
Conference paper	881

Table 1: Key Aspects of the Investigation.

3.1 Research Design

Research design would likely include the following components:

1. Research Objectives: Clearly defined objectives focusing on understanding the evolution of AI in Intelligent Tutoring Systems, identifying key trends, influential authors, institutions, and the impact of AI on educational technologies.
2. Data Collection: Bibliographic data is systematically collected using the keyword artificial intelligence and intelligent tutoring system from the Scopus database, a widely-used repository of academic publications, ensuring a comprehensive coverage of relevant literature.
3. Inclusion and Exclusion: Using the PRISMA flowchart, the researchers apply rigorous inclusion and exclusion criteria to filter the retrieved articles, ensuring that only studies meeting specific criteria are included in the analysis.
4. Data Analysis: data analysis is conducted using Biblioshiny, a tool designed for bibliometric analysis. This step involves quantitative examination of publication trends, citation patterns, trend topics and co-authorship networks, among other bibliometric indicators.
5. Visualization: VOSviewer and Citespace software are employed to create visual representations of the bibliometric data. These tools facilitate the exploration of citation networks, identification of research clusters, and visualization of co-authorship and co-occurrence relationships.
6. Interpretation: The researchers interpret the findings of the bibliometric analysis, drawing insights into the evolution of educational technologies in the context of intelligent tutoring systems powered by AI. They may also discuss the implications of their findings for future research directions and educational practice.

4. RESULTS

4.1 Annual Scientific production

The figure shows the fluctuating volume of academic articles from 1984, with an early peak around 1990 suggesting initial fervor in the field. This peak passes on to an unrestrained phase, where the amount of publications sharply changes, probably replicating changing research urgencies or outward influences on academic focus. By the late 1990s, a more steady growth outline comes up, representing continued interest and possibly the progress of foundational research in the research field. However, this steadiness is interrupted by a design of peaks and valleys after 2008, suggesting periodic discoveries or swings in research intensity. A momentous downturn after 2020 may be associated with the unsettling impact of the COVID-19 epidemic on research happenings or a broader evolution within the academic sphere. The graph completes with a blunt drop, likely motioning incomplete data for the newest year or a disturbing decline in scholarly output.

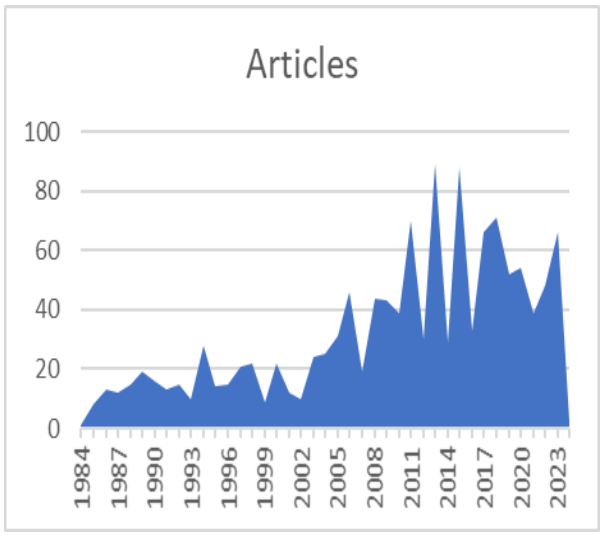

Figure 2: Annual Scientific Article Production From 1984 To 2024

4.2 Most Relevant Authors

Most Relevant Authors provides a visual representation of author productivity in the domain of Intelligent Tutoring Systems (ITS) and Artificial Intelligence (AI), with the x-axis quantifying the number of documents published. The most prolific author leads the field with 32 documents, followed by others with 27 and 21, indicating a hierarchy of output and, potentially, influence within the academic community. The remaining authors show a more uniform distribution of publications, with their contributions ranging from 12 to 16 documents, suggesting a robust group of active researchers contributing to the body of knowledge in ITS and AI.

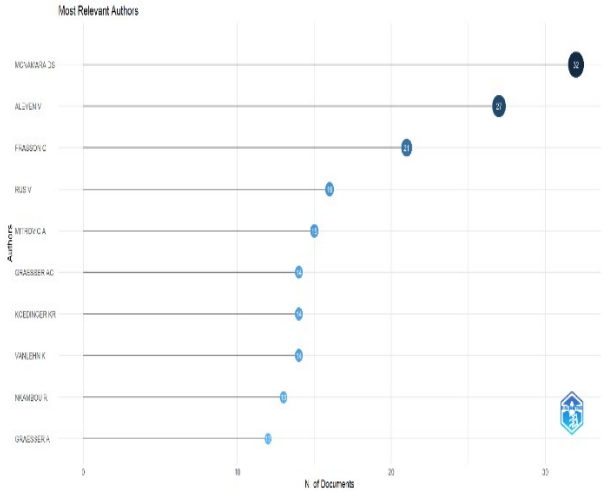

Figure 3 Most Relevant Authors

4.3 Most Relevant Source

The figure 4 shows major publication locations in the sphere of Intelligent Tutoring Systems (ITS) and Artificial Intelligence (AI), with "Lecture Notes in Computer Science" in the forefront with a substantial edge of 328 articles, signifying it is a principal source for high-impact research in this particular field. Next in line is "CEUR Workshop Proceedings" with 62 papers, highlighting the part of workshops in nurturing pioneering discussions and research demonstrations. The "International Journal of Artificial Intelligence in Education" depicts its role focus with 27 papers, underlining its steadfast audience and particular subject matter. National conferences also perform an important role, as realized with the "Proceedings of the National Conference on Artificial Intelligence" sharing 19 papers to the research in AI. An anonymous source that has 17 papers pinpoints a possible incongruity in data recording, yet it still replicates the diverse platforms where ITS and AI research is distributed.

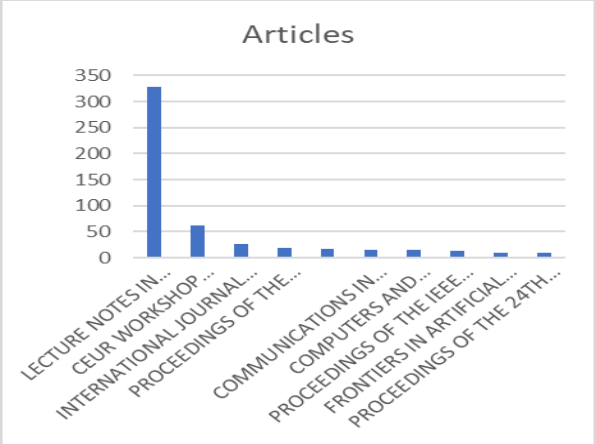

Figure 4 Most Relevant Sources

4.4 Most Global Cited Documents

The top 10 most cited documents in Intelligent Tutoring Systems (ITS) and Artificial Intelligence (AI) highlight their profound impact and influence in these fields. The paper by WHITEHILL J, 2014, in IEEE Transactions on Affective Computing, leads with 411 citations, indicating its significant role in affective computing and AI, especially in emotional AI or human-computer interaction. Close behind, with 410 citations, is CONATI C's 2002 work on user modeling and adaptation in USER MODELING AND USER-ADAPTED INTERACTION, underscoring its importance in personalized learning and AI interfaces. ANDERSON JR's

1985 publication, with 376 citations, appears to be a foundational piece in cognitive science or AI, evidenced by its enduring relevance. D'MELLO S's 2007 paper in IEEE Intelligent Systems, having 289 citations, likely delves into intelligent systems, a central theme in AI applications. YUDELSON MV's 2013 work in Lecture Notes in Computer Science, with 279 citations, seems to explore computational science in AI or ITS. GRAESSER AC's 2001 article in AI Magazine, cited 275 times, potentially covers a broad spectrum of AI topics. ROLL I's 2016 paper in the International Journal of Artificial Intelligence in Education, with 261 citations, focuses on AI's role in education, a pivotal aspect of ITS. HWANG G-J's 2003 publication in Computers & Education, having 221 citations, signifies key developments at the intersection of computing and education, relevant to ITS. NWANA HS's 1990 article in Artificial Intelligence Review, with 216 citations, is likely a foundational review piece in AI. Lastly, VELASQUEZ JUAN D's 1997 paper presented at the National Conference on Artificial Intelligence, having 196 citations, indicates substantial contributions to AI at that time. This analysis reveals a blend of seminal and more recent works, spanning topics like affective computing, user modeling, AI in education, and intelligent systems. The high citation counts of these papers affirm their significant role in shaping contemporary research and applications in ITS and AI. These topics reflect the interdisciplinary nature of these fields, integrating insights from education, psychology, computer science, and beyond.

Table 3 Most Globally Cited Documents

Paper	DOI	Total Citations	TC per Year	Normalized TC
WHITEHILL J, 2014, IEEE TRANS AFFECTIVE COMPUT	10.1109/TAFFC.2014.2316163	411	37.36	15.14
CONATI C, 2002, USER MODELL USER ADAPT INTERACT	10.1023/A:1021258506583	410	17.83	6.86
ANDERSON JR, 1985,	10.1126/science.228.4698.456	376	9.4	7.77
D'MELLO S, 2007, IEEE INTELL SYST	10.1109/MIS.2007.79	289	16.06	10.85
YUDELSON MV, 2013, LECT NOTES COMPUT SCI	10.1007/978-3-642-39112-5_18	279	23.25	19
GRAESSER AC, 2001, AI MAG		275	11.46	7.21
ROLL I, 2016, INT J ARTIF INTELL EDUC	10.1007/s40593-016-0110-3	261	29	7.35
HWANG G-J, 2003, COMPUT EDUC	10.1016/S0360-1315(02)00121-5	221	10.05	6.23
NWANA HS, 1990, ARTIF INTELL REV	10.1007/BF00168958	216	6.17	12.39
VELASQUEZ JUAN D, 1997, PROC NATL CONF ARTIF INTELL		196	7	14.97

Figure 5 encapsulates the citation landscape of authors within the realm of artificial intelligence in intelligent tutoring systems research. The map is constructed with a specific inclusion criterion—a minimum of five citations per document—yielding a subset of 548 documents from a larger corpus of 1283, thus focusing on the more prominent contributions within the field. Nodes, varying in size, represent individual authors or co-author groups, with larger nodes signifying a higher citation count and, by implication, a greater impact or prominence.

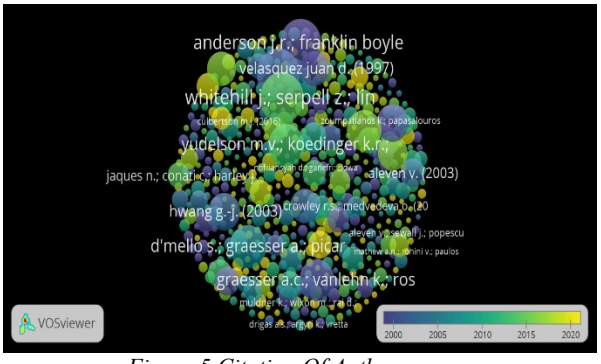

Figure 5 Citation Of Authors

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4.5. Countries' Scientific Production

Figure 6 encapsulates the scientific production across a range of countries, with the USA leading significantly, boasting a frequency of 1619, which dwarfs the outputs of other nations like Canada and China, with frequencies of 220 and 203, respectively. This distinctive inconsistency may replicate the USA's extensive research structure and considerable investment in technology and science. After the USA, China, and Canada we see the UK, Spain, Brazil, Mexico, India, Japan, and Germany recording the lowest frequency at 89.

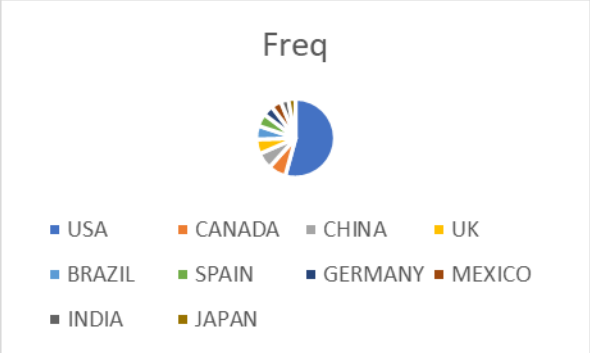

Figure 6 Shows The Scientific Production Of Various Countries.

4.6. Trend Topics

The trend topics visualization exemplifies the developing scenario of artificial intelligence in intelligent tutoring system studies ranging from 1988 to 2022. It divulges a sequential development of main areas, opening with introductory ideas like "computer-assisted instruction" and continuing towards more cutting-edge AI applications such as "machine learning" and "natural language processing systems." The growing term occurrences for "e-learning" and "machine learning" in recent years underline a rush in interest, likely driven by the global change to digital education. The scope of the bubbles, signifying term frequency, recommends the heaviness of each subject within the intellectual discourse, with bigger bubbles in recent years underscoring the rising eminence of AI in producing adaptive, tailored learning practices. This chronology effectively displays the dynamic changes and development of AI's role in educational technologies over the previous three decades.

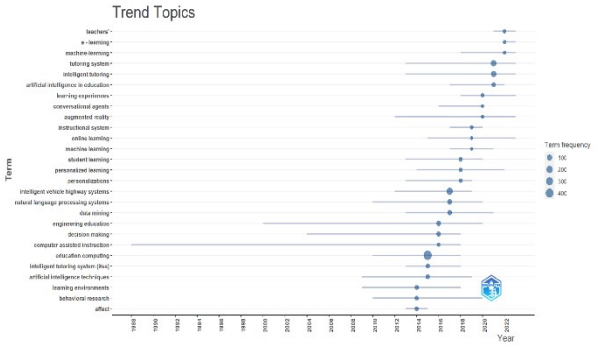

Figure 7 Displays A Visual Representation Demonstrating The Popularity Of Various Topics.

4.7. Thematic Map

The thematic map given seems to classify numerous topics linked to artificial intelligence in intelligent tutoring systems (ITS) study based on two dimensions: development degree (density) and relevance degree (centrality).

Niche Themes (High density, Low centrality): These topics, such as "human", "humans" and "article", have a robust internal progress within the research but are less associated to other themes. They may characterize particular areas that are sophisticated but presently operate in more remote research niches.

Motor Themes (High density, High centrality): "computer-aided instruction ","Artificial intelligence" and "intelligent tutoring system" can be quantified into this quadrant. These are sophisticated and introductory themes that are extremely entangled with other research fields driving the field forward. Their high centrality specifies they are expected to be essential concepts that reinforce a wide collection of studies in ITS.

Emerging or Declining Themes (Low density, Low centrality): "Learning", "educational technology", and "medical education" might be either new areas that are starting to gain attention but are not yet fully explored, or older areas that are becoming less central to the field.

Basic Themes (Low density, High centrality): Themes such as "teaching", "intelligent tutoring systems", and "knowledge-based systems" are identified as basic. They are important to the field but might not be as developed as the motor themes. They are central, indicating their relevance and potential for further development.

This thematic map is a strategic tool for identifying the structure and evolution of research within ITS. It highlights which areas are

mature and central, which are niche and highly developed but less connected, and which are either emerging, growing, or on the decline in terms of focus within the research community.

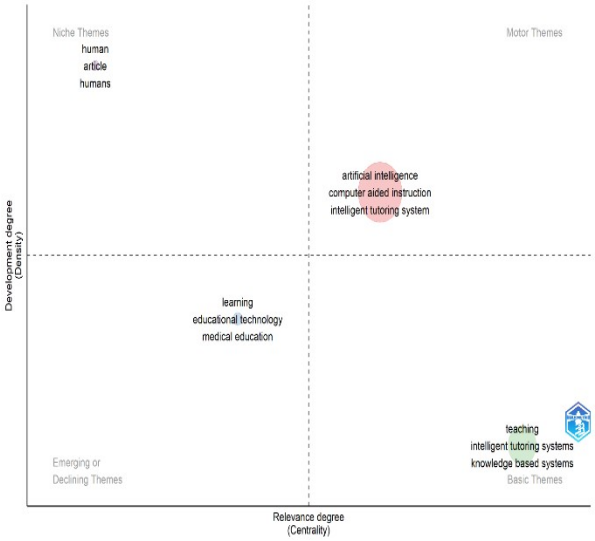

Figure 8 Thematic Map

4.8. Conceptual Structure Map using Multiple Correspondence Analysis

Multiple Correspondence Analysis (MCA) is utilized to illustrate the conceptual arrangement of the subject area, enabling the identification of document clusters that share similar ideas. The conceptual structure map, generated through multiple correspondence analysis, consolidates relevant keywords while considering their cohesion within the network. Figure 9 delineates four distinct clusters that encapsulate the diversity of research themes within artificial intelligence (AI) and intelligent tutoring systems (ITS). The red cluster, predominantly on the negative side of the first dimension and neutral on the second, likely represents fundamental concepts in AI and ITS—core technologies and methodologies that form the backbone of the field. The blue cluster, straddling the centre of the first dimension and leaning positive on the second, suggests an integration of educational theories with practical AI applications, indicating a research focus on leveraging AI algorithms to augment the learning process through ITS. Looking at the green bunch, which inhabits a positive space on both proportions, we see a federation of cutting-edge and focused topics, possibly indicative of the innovation in AI research, with terms like "knowledge representation" and "multi-agent systems" stressing an aggregation on technically sound systems envisioned for difficult educational communications. Finally, the purple group, existing in the negative group of both dimensions, points fingers at basic AI processes like "natural_language_processing", sustaining a range of software beyond education. An all-encompassing assessment of the AI and ITS research landscape is received from these clusters grouped, stressing predominant technologies, practical and theoretical syntheses, borderline research areas, and the indispensable AI developments that permit varied applications within the field.

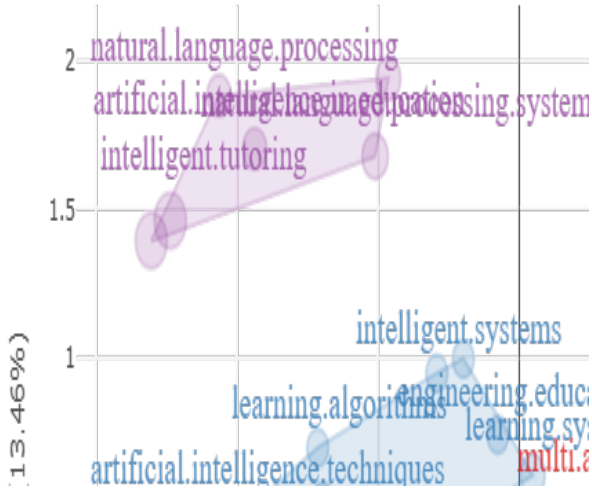

Figure 9 Depicts A Conceptual Arrangement Of The Subject Area.

4.9. Bibliographic Coupling of Authors

The bibliographic coupling of authors is a phenomenon where researchers are connected through their mutual citation of common references, creating a methodological link between their publications. This coupling can be quantified, with the strength of the connection proportional to the number of shared references. This network visualization reflects the bibliographic coupling among authors in artificial intelligence in intelligent tutoring systems (ITS) research, highlighting 964 authors out of an initial 1218. These authors meet the set threshold of having at least one document and one citation each, signifying their engagement in the field. The map is structured into 614 items and 28 distinct clusters, indicated by various colors, which denote thematic or methodological groupings where authors are interconnected based on shared references in their scholarly works.

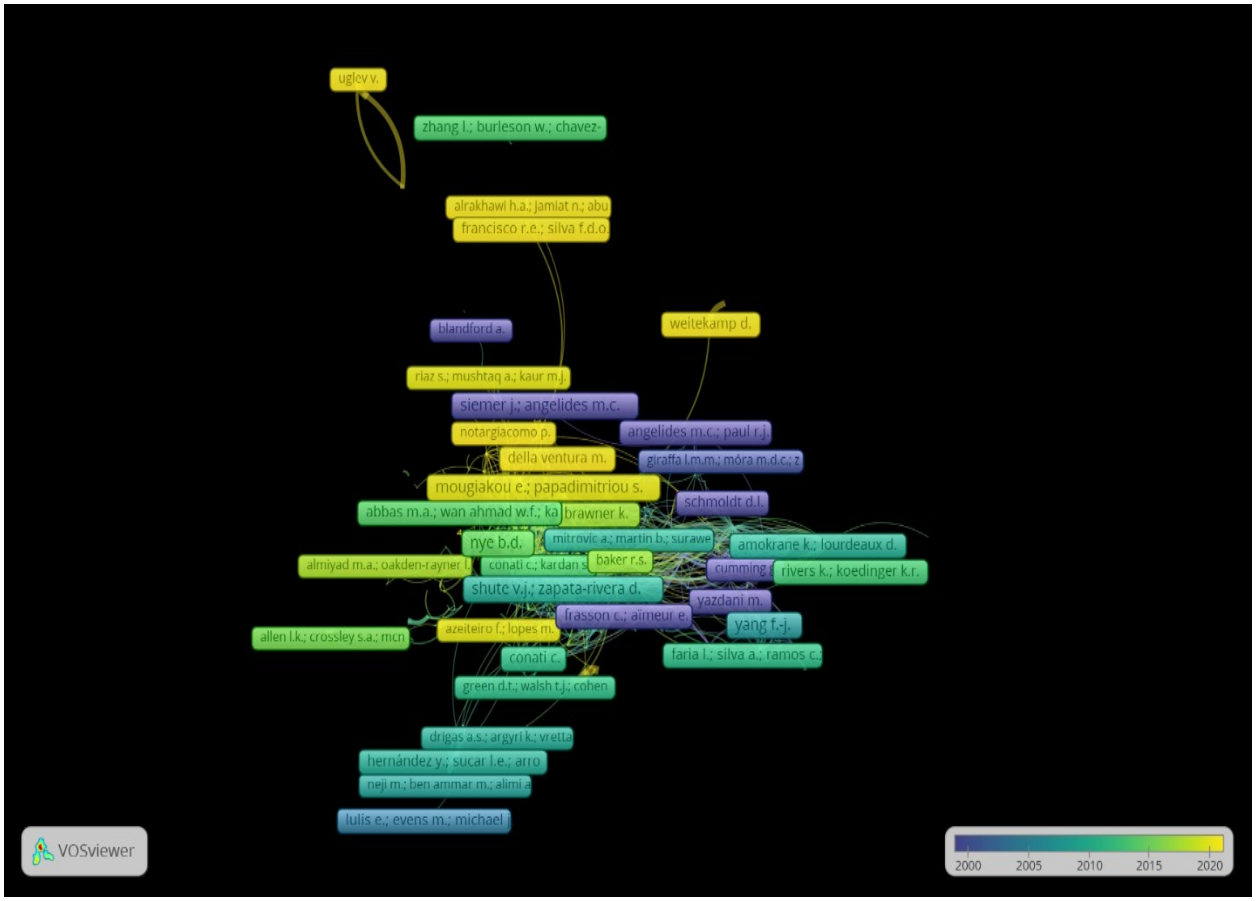

Figure 10 Bibliographic Coupling Of Documents

4.10. Co-occurrence of all keywords

Figure 11 displays a keyword co-occurrence network related to the use of artificial intelligence in intelligent tutoring systems research, segmented into 11 distinct color-coded clusters based on a threshold of at least five occurrences. Out of 5795 total keywords, 386 have qualified for inclusion in this visualization. These clusters group keywords that frequently appear in conjunction, indicating thematic linkages within the scholarly material. Cluster 1, depicted in red, encompasses 57 keywords and signifies core themes in AI and ITS research. Cluster 2, in green, consists of 54 keywords, delineating a closely associated yet distinct thematic segment. Cluster 3, colored blue, with 50 keywords, reflects another interrelated area of study. Cluster 4, shaded yellow, includes 48 keywords that relate to a particular research niche. Cluster 5, in purple, with 38 keywords, indicates a specialized topic within the field. Cluster 6, shown in teal, with 35 keywords, and the subsequent clusters—Cluster 7 in orange with 33 keywords, Cluster 8 in light brown with 22 keywords, Cluster 9 in pink with 21 keywords, and Clusters 10 and 11, both with 14 keywords, in light green and gray, respectively—each represent distinct yet interconnected research subthemes within the broader domain of AI in ITS.

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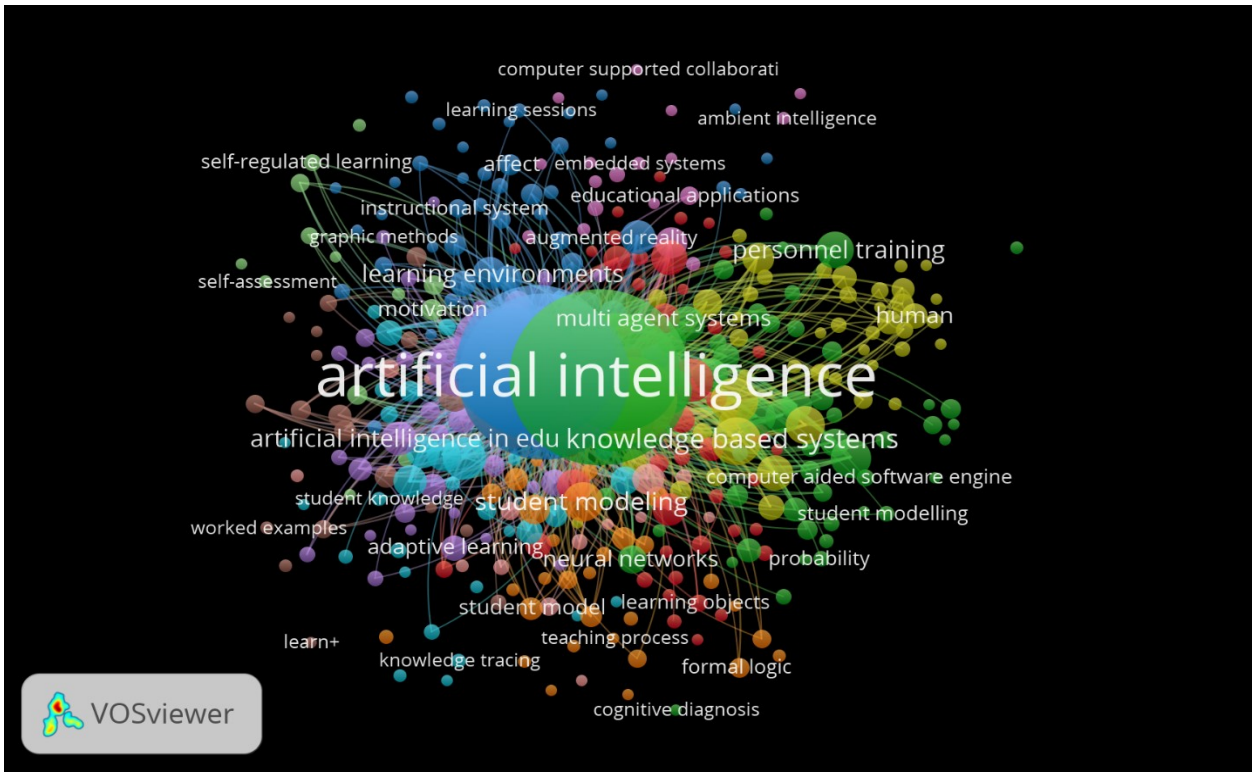

Figure 11 Co-Occurrence Network Map Of All Keywords

In the research domain, the keyword "Artificial Intelligence" emerges as the most prominent, with 1015 occurrences and a substantial total link strength of 7655, signifying its central importance and extensive interrelation with other research topics. Closely following is "Computer Aided Instruction," registering 906 occurrences and a link strength of 7456, illustrating its near-equal prominence and connectivity in the field. The term "Intelligent Tutoring System" also features heavily with 789 mentions and a link strength of 6368, reflecting its significant role in educational technology research. "Education Computing" and "Intelligent Tutoring Systems" indicate a strong technological focus within the educational sphere, with occurrences of 494 and 388, and link strengths of 4365 and 3592, respectively. The keyword "Students" surfaces 325 times and has a notably high link strength of 3599, highlighting the learner-centered orientation of this research area. "Learning Systems" and "Teaching," with 240 and 217 occurrences and link strengths of 2933 and 2367, respectively, point to the broader systems and methodologies underpinning educational practices. The general term "Education," with 200 occurrences and a link strength of 1889, frames the overarching context for these technological applications. Lastly, "E-Learning" appears 146 times with a link strength of 1483, underscoring the increasing relevance of online educational environments. Together, all these keywords describe a research scenario deeply intertwined with technological developments intended to inspire educational surroundings, with a vigorous network of systematized themes giving prominence to the collaboration between technology and teaching.

Table 4: Most Occurring Keywords.

Keyword	Occurrences	Total Link Strength
Artificial Intelligence	1015	7655
Computer aided Instruction	906	7456
Intelligent tutoring system	789	6368
Education Computing	494	4365
Intelligent	388	3592

tutoring systems		
Students	325	3599
Learning Systems	240	2933
Teaching	217	2367
Education	200	1889
E-Learning	146	1483

4.11. Top 20 keywords with the strongest citation bursts

The maximum noteworthy and dynamic topics in artificial intelligence and intelligent tutoring systems study ranging a period from 1984 to 2024 is identified by way of citation bursts of 20 top keywords. Early in the 1980's we find attention gaining on "teaching machines" which is suggestive of basic interest in teaching aids that are automated, while the keyword "knowledge-based systems" had early attention on "teaching machines" in the 1980s suggests initial interest in automated teaching aids, while the continuing interest on "knowledge-based systems" until 2006 replicates the enduring impact of AI basics in education. The sustained and vigorous attention to "intelligent tutoring systems" until 2007 goes along with the progress of custom-made learning atmospheres. The citation burst for "computer simulation" till 2006 designates an emphasis on practical, collaborative learning tools, and the continuous consideration to "expert systems" until 2004 demonstrates the significance of AI in managerial developments within education. To note, the fresh citation bursts for "intelligent vehicle highway systems" ranging from 2015 to 2024, "machine learning" within 2016 to 2024, and "intelligent tutoring" from 2021 to 2024, highlight a present-day research pivot to progressive AI applications in education, possibly driven by the modern technological developments. These bursts not only replicate the progress of research topics over time but also highlight the mounting complexity and incorporation of AI technologies in ITS. The power of the bursts specifies the concentration and effect of these topics throughout their particular time frames, signifying where scholars have focused their exertions and suggesting at future guidelines in ITS and AI research.

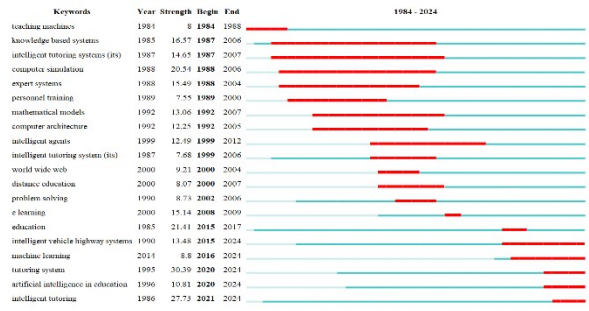

Figure 12 Displays The Keywords That Have The Strongest Citation Bursts

4.12. Co-Citation of Cited Authors

Visualization of a co-citation cluster network amongst cited writers is a graphical depiction that plots the associations between authors based on how often their work is cited together in other scholarly documents. Each node represents an author, with the node's size indicating the author's co-citation frequency, thus reflecting their influence in the field. Lines connecting the nodes, or edges, signify co-citations, whereas thicker lines denote a higher frequency of co-citation, suggesting stronger collaborative or thematic ties between authors. Clusters of closely interconnected nodes emerge, highlighted in different colors, each representing a group of authors often cited together, likely indicating a shared research focus or collaborative group. The network consists of 20 clusters and the figure illustrates the major clusters. luster #0 - Knowledge-Based Tutor: This cluster is the largest with 159 members, featuring ANDERSON JR and BROWN JS as the most cited authors. The cluster's focus is on systems that incorporate knowledge-based approaches to teaching communication skills, as indicated by the silhouette value of 0.884, which suggests a high level of thematic coherence. Cluster #1 - Affective State: With 148 members and prominent authors like VANLEHN K, GRAESSER AC, and CONATI C, this cluster centers on the affective components of learning within ITS. The silhouette value of 0.732 implies a well-defined focus within the cluster on the emotional aspects of learning. Cluster #2 - Computational Model: Comprising 97 members, this cluster includes key contributors such as KOEDINGER KR, ALEVEN V, and MITROVIC A. The research here is characterized by the development of computational frameworks for ITS, with a silhouette value of 0.809 indicating cohesive research activity. Cluster #3 - Artificial

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Intelligence: With 92 members, this cluster is represented by ROLL I, KULIK JA, and NYE BD. It reflects the application of AI principles in the educational space, with a silhouette value of 0.733 highlighting its integration within the ITS field. Cluster #4 - Conversational Intelligent Tutoring System: This cluster contains 85 members and is led by MCNAMARA DS, CHI M, and AZEVEDO R. The focus is on the advancement of natural language dialogue systems in ITS, as suggested by a silhouette value of 0.791. Cluster #5 - Literature Review: With 83 members, this cluster's top authors are MURRAY T, BULL S, and MA W, emphasizing the role of literature reviews in synthesizing ITS research, indicated by a silhouette value of 0.786. Cluster #6 - Web-Based Intelligent Tutoring System: It has 73 members and is highlighted by BRUSILOVSKY P. The research here addresses the deployment of ITS on-web platforms, with a silhouette value of 0.799 pointing towards significant contributions to the scalability and accessibility of ITS. Cluster #7 - Remedial Tutoring: This cluster includes 71 members with WOOLF BP and WENGER E as the most cited authors. The silhouette value of 0.887 indicates a strong internal consistency in research aimed at supporting learners requiring additional help through ITS.

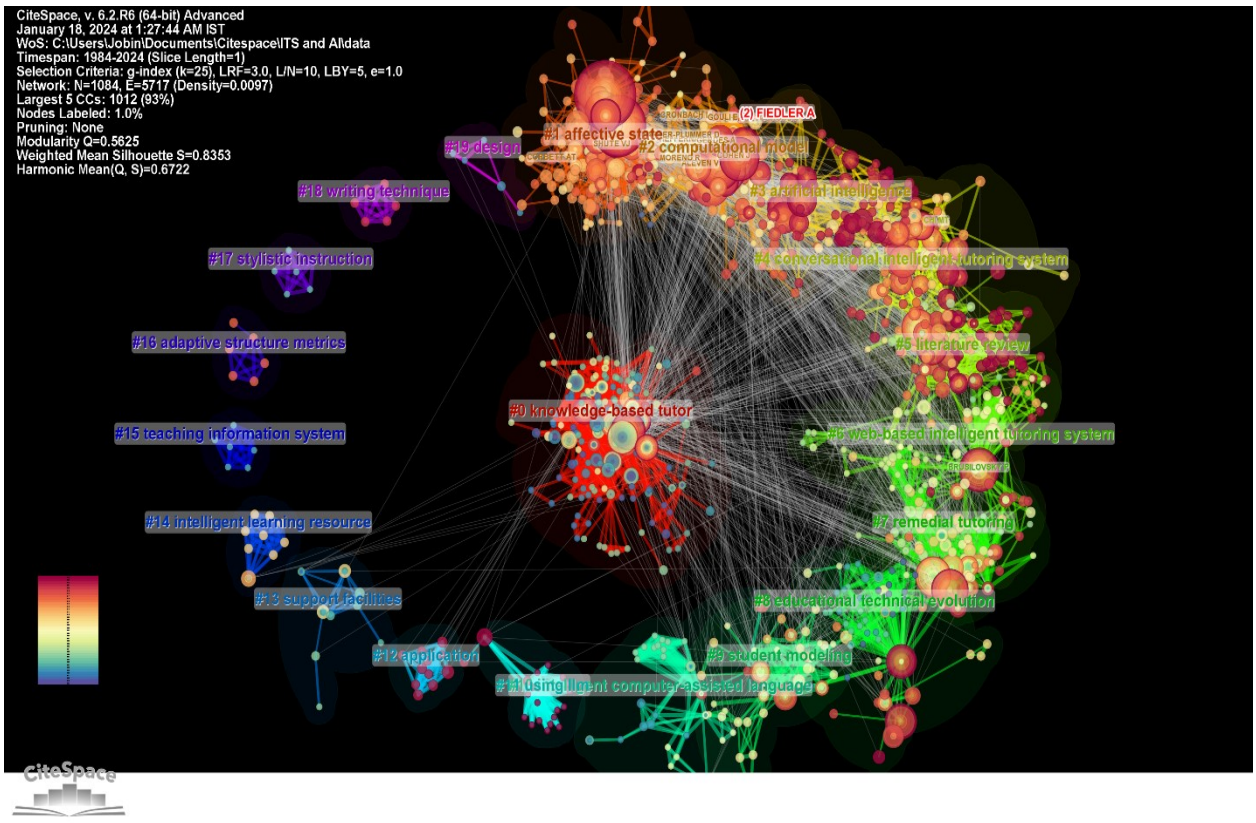

Figure 12 Shows A Clustered Network Visualization Of The Authors Who Have Been Cited In The Research

4.13. Timezone Network Visualization of Cited Journals

The timeline visualization illustrates the cited journals within the research realm. It spans from 1984 to 2024. The visualization consists of nodes, each symbolizing a cited reference of a journal article, with the size of a node indicative of its citation frequency within a particular time slice. The color-coding of the nodes matches the color bar at the bottom left, denoting the chronological progression of citations from the earliest at the bottom to the most recent at the top. The visualization's background is striped vertically, representing the timeline divided into slices, typically by year. The network consists of 15 clusters and the figure illustrates major clusters. Cluster #0 – Multi-modal Pedagogical Conversational: This is the largest cluster with 143 members, showing a significant silhouette value of 0.636, which indicates a reasonably

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good internal consistency within the cluster. The cluster is significantly influenced by a literature review by Ilić (2023) on intelligent techniques in e-learning. Cluster #1 – Computer-Assisted Learning: With 94 members and a high silhouette value of 0.707, this cluster centers on computer-assisted learning and intelligent tutoring systems, with a slight mention of writing techniques. The most cited works include topics on cognitive science and artificial intelligence, influenced by Vandewaetere's work on advanced technologies for personalized learning. Cluster #2 – Intelligent Tutoring System: This cluster has 82 members with the highest silhouette value among the top three clusters (0.745), indicating very cohesive internal consistency. It focuses exclusively on intelligent tutoring systems and metacognitive reasoning, with Faria's article on training control centers' operators being the major citing work. Cluster #3 – Vicarious Learning: Comprising 81 members with a silhouette value of 0.72, this cluster addresses vicarious learning strategies within intelligent tutoring systems. The significant influence comes from Guan's 2020 analysis of AI innovation in education. Cluster #4 – Teaching Collaborative Skill: This cluster, with 57 members and a high silhouette value of 0.824, indicates a strong, well-defined focus on collaborative skills in teaching, again within the context of intelligent tutoring systems. The major citing article is the same as in Cluster #0, suggesting overlapping interests or a shared research focus. Cluster #5 – Ontology-Driven Architecture: With 55 members and a silhouette value of 0.738, this cluster delves into the architecture behind intelligent tutoring systems, specifically ontology-driven structures, with Lippert's article on conversational intelligent tutoring systems being pivotal.

The "Lecture Notes in Computer Science" series stands out as the most influential in the field of artificial intelligence and education, with a substantial 328 citations and a total link strength of 3290, underscoring its central role in disseminating pivotal research. Journals such as the "International Journal of Artificial Intelligence in Education" and "Computers and Education" demonstrate significant impact, with citations at 27 and 15, respectively, and high total link strengths of 1176 and 958, indicating their articles are often seminal to the discourse in educational AI. Meanwhile, conference proceedings like those of the "IEEE International Conference on Systems, Man and Cybernetics" and the "International Florida Artificial Intelligence Research Society" contribute notably to the field, albeit with a more modest influence, as reflected by their lower citation numbers and total link strengths.

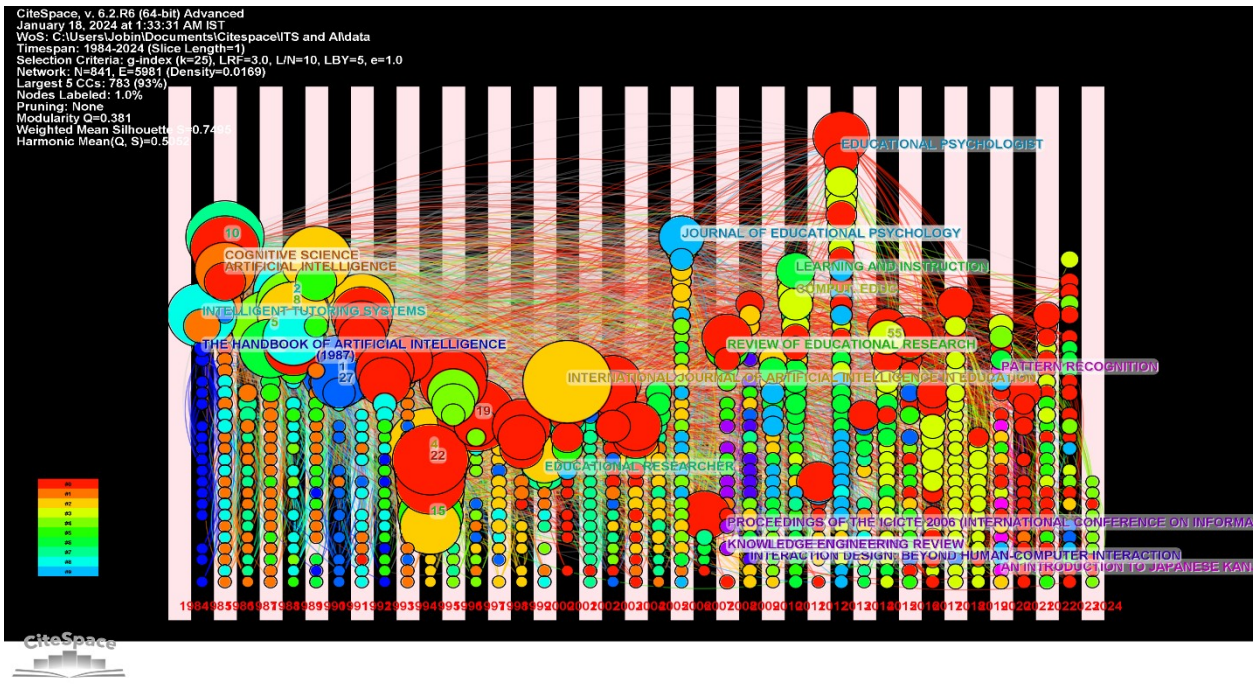

Figure 13 Shows A Visualization Of The Time Zone Network Of The Cited Journals.

4.14. Timeline Visualization of Country's Collaborations

The timeline view of country collaborations in the bibliometric exploration of artificial intelligence in intelligent tutoring systems exhibits a varied and globally interrelated research setting, as shown by eleven major clusters. Cluster #0, labeled "Systematic Review," has strong contributions from the United States, Germany, and Spain, indicating that these countries are key players in publishing systematic reviews within the domain of intelligent tutoring systems. This cluster's major work is by McCarthy, highlighting strategy training for Spanish speakers. In Cluster #1, "Educational Game," Canada, the United Kingdom, and China are the most cited, suggesting they are influential in the development and research of educational games that incorporate intelligent tutoring systems. The leading article for this cluster comes from Leung, focusing on an inquiry-based genomics intelligent tutoring system. Cluster #2, "Bibliometric Analysis," sees India, Taiwan, and Malaysia as the most cited, which could imply these countries are central to bibliometric research in artificial intelligence. Singh's work on a custom-tailored intelligent tutoring system stands out as a major citing article here."Mixed-Initiative Handwriting Game" is the theme of Cluster #3, with France, Morocco, and Belgium being the prominent contributors. Sarr's article on a mixed-initiative game for preschoolers is a significant citation, indicating a focus on early education technology. Cluster #4, "Educational Data," shows South Korea, Singapore, and Croatia with the most citations. Smolin's research on applying AI to educational data analysis is noteworthy here, emphasizing the importance of data analysis in education.

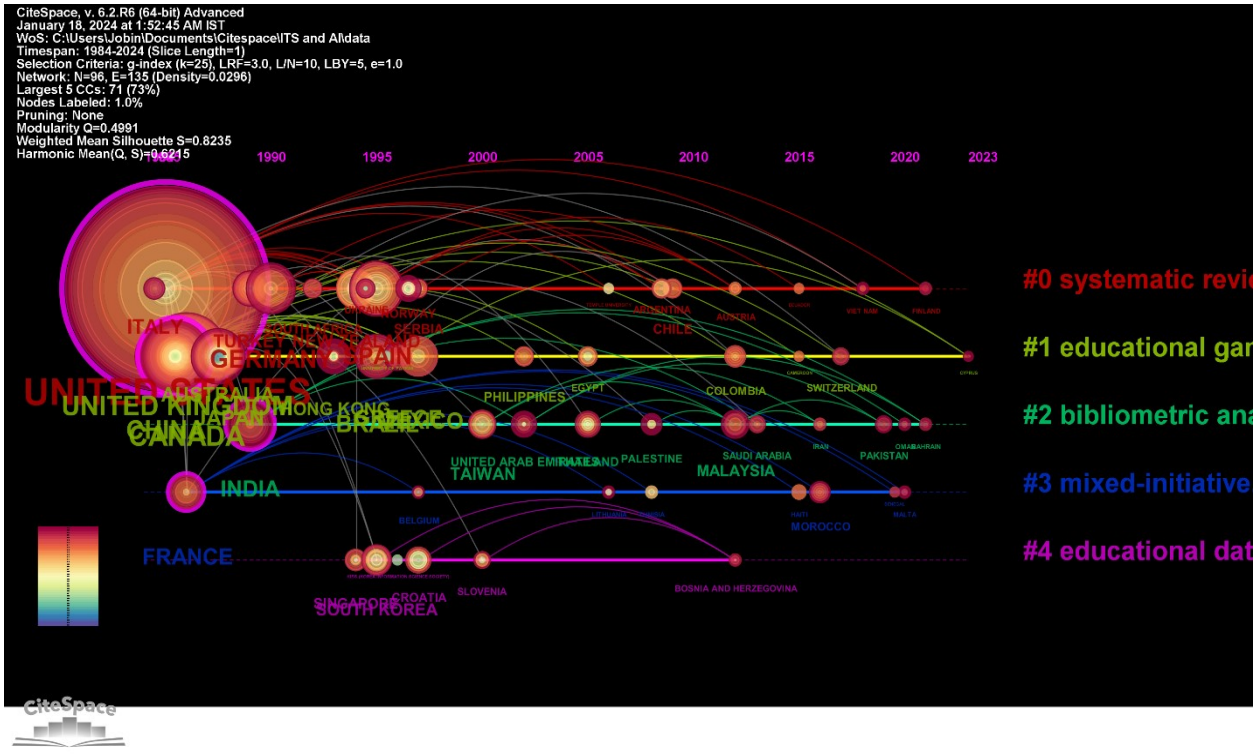

Figure 14 Timeline Network Visualization Of Countries Collaborations

5. DISCUSSION

The artificial intelligence in intelligent tutoring systems, spanning from (1984 to 2024) encompasses 493 sources including journals, books, and other documents, amounting to a total of 1283 documents with an annual growth rate of 1.75%. The average age of a document is 13.2 years, with each document receiving an average of 12.51 citations, and the total number of references cited across all documents is 26,838. Authors have contributed to this body of work with a count of 2819, among which 176 have authored documents on their own; however, the documents typically have 3.18 co-

authors, with 11.93% of the documents featuring international collaborations. The majority of the documents are conference papers (881), followed by articles (363), and a smaller number of book chapters (39). Annual scientific production from 1984 illustrates an initial surge in publications, followed by periods of volatility and stabilization, with a notable decline post-2020 that could be tied to the COVID-19 pandemic's impact or shifts in the field's dynamics, concluding with a sharp decrease that suggests either incomplete recent data or a concerning reduction in research output. The "Most Relevant Sources" underscores "Lecture Notes in Computer Science" as the predominant source with 328 articles, highlighting its centrality in the ITS and AI research landscape, followed by specialized forums such as "CEUR Workshop Proceedings" and the "International Journal of Artificial Intelligence in Education," which indicate the diversity and depth of discourse in these academic fields. The analysis of the most globally cited documents demonstrates the interdisciplinary richness and developmental milestones of the field, with WHITEHILL J.'s leading work in affective computing and CONATI C.'s influential research on adaptive learning environments marking them as cornerstones in the evolution of educational technologies and user interaction within AI. The scientific production by country in the field of Intelligent Tutoring Systems and Artificial Intelligence shows the USA at the forefront with 1619 publications, followed by a considerable gap with Canada and China at 220 and 203 respectively, indicating the USA's dominant role in research output within these domains. The trend topics from 1988 to 2022 in the domain of artificial intelligence applied to intelligent tutoring systems reflect a shift from early "computer-assisted instruction" to cutting-edge areas like "machine learning," with growing emphases on "e-learning" and "natural language processing systems," indicating a strong alignment with digital education advancements. The thematic map categorizes topics in artificial intelligence and intelligent tutoring systems research, showing that "artificial intelligence" and "computer-aided instruction" are central and well-developed motor themes, indicating their foundational role in the field. In contrast, "human" and "article" are identified as niche themes, which, despite their well-developed status, remain less connected to the broader discourse, possibly suggesting areas of specialization that have yet to intersect significantly with other research avenues.

The bibliographic coupling map of authors in artificial intelligence and intelligent tutoring systems research encapsulates 964 out of 1218 authors, structured into 28 clusters and 614 items, illustrating the interconnectedness of authors through shared references and indicating thematic groupings within the scholarly community. The keyword co-occurrence network, consisting of 386 out of 5795 total keywords, discloses the thematic intricacy of artificial intelligence in intelligent tutoring systems studies through 11 color-coded groups. The network, demonstrating the affiliations of terms like "Artificial Intelligence," "Intelligent Tutoring System," and "Computer Aided Instruction," underlines the centrality and connection of these notions in the field, replicating a rich intricacy of research themes extending from technological developments to educational procedures. Koedinger K.R. stands as the most co-cited author for his prominent contributions, trailed by significant scholars like Graesser A.C., Aleven V., and VanLehn K., who jointly form the mainstay of this academic field. The link strength and high citation counts of these authors accentuate their paper's centrality and the interrelated feature of their research in the scholarly network. The picture accentuates the compactness and progress of academic focus across time, with greater nodes symbolizing more recurrently cited journals, and clusters disclosing thematic amassing within the research scenario. The timeline picturing of country partnerships in artificial intelligence and intelligent tutoring system study exposes a dynamic and interrelated global research network by way of eleven main groups, with nations like the United States, Spain, and Germany topping in methodical reviews, and countries like Canada, China and the UK being noteworthy in didactic gaming research. This visualization exemplifies a varied involvement with changing focal points, such as bibliometric synthesis led by Malaysia, India, and Taiwan and educational data synthesis led by South Korea, Croatia, and Singapore highlighting the international opportunity and dedicated interests within the research area.

6. RESEARCH GAPS

Research Gaps: Numerous research gaps were identified by the use of bibliometric analysis of intelligent tutoring systems (ITS) and artificial intelligence (AI). Initially, while basic concepts such as "computer-assisted instruction" have progressed into intricate themes such as "machine learning," there seems to be an absence of inclusive research connecting these basic methods with modern AI techniques. This gap recommends a need for research that takes into consideration traditional educational approaches with contemporary AI-driven methods. Next, the thematic graph specifies that niche themes like "human" and "article" are sophisticated, but they function in isolation. This points to a potential gap in interdisciplinary research that could connect these niche areas more effectively with central ITS themes. Additionally, emerging or declining themes such as "learning" and "medical education" highlight areas that are either on the cusp of development or waning in focus. These trends suggest opportunities for new research to invigorate these topics or to understand the reasons for their decline.

Practical Implications: The identification of trend topics and citation bursts has practical implications for the development and application of ITS. The surge in terms like "e-learning" and "machine learning" emphasizes the need for practical ITS solutions that leverage these technologies, particularly in the current global context that favours digital education. For educational technology developers and practitioners, the focus on "machine learning" from 2016 to 2024 indicates a clear directive to incorporate adaptive learning algorithms into ITS design. The prominence of "intelligent tutoring" from 2021 to 2024 suggests that ITS should prioritize simulating one-on-one tutoring experiences. For policymakers and educators, the strong citation bursts for "intelligent vehicle highway systems" and "artificial intelligence in education" underscore the importance of AI in broader educational policies and curriculum development, advocating for ITS integration across various educational levels and disciplines. This bibliometric analysis, therefore, not only informs future research trajectories but also guides current educational practice and policy toward integrating AI effectively into learning environments.

7. LIMITATIONS

This study solely relies on publications indexed in the Scopus database include the potential omission of relevant articles not included in Scopus, leading to a limited scope of the literature review. Additionally, the findings may not fully represent the entire landscape of research on this topic, as some studies from niche or emerging journals not indexed in Scopus may be overlooked.

8. CONCLUSION

This bibliometric study, leveraging the extensive coverage of the Scopus database and adhering to the PRISMA flowchart for inclusion and exclusion, provides a comprehensive analysis of the integration of Intelligent Tutoring Systems (ITS) and Artificial Intelligence (AI). The results disclose key perceptions of the yearly scientific production, highlighting the maximum pertinent authors, sources, and internationally cited papers in the field. The most productive country was the US according to the study showing that it had a significant influence on AI and ITS research. The research also studies trending topics, and engaging tools like thematic maps, factorial analysis, and bibliographic coupling to plot the interrelation and thematic development within the field. Furthermore, the co-occurrence of keywords and co-citation of authors provides light on the significant themes and collective networks sustaining the research community. The network picturization of cited journals and timelines of international collaborations additionally highlight the global and interdisciplinary characteristics of this research domain. From these understandings, the study proposes three future directions: Primarily to boost interdisciplinary research, and accentuate the richness and depth of ITS and AI research by participating in diverse viewpoints and methodologies. Secondly, to increase international collaborations, expanding the research scenario beyond the present majority of the United States, thereby elevating the global influence and reach of ITS and AI research. Lastly, to concentrate on developing technologies and their applications within ITS, guaranteeing the field remains at the lead of educational modernization and endures to evolve in significance and impact. These commendations aim to connect the recognized

research gaps and strengthen the practical consequences of ITS and AI, setting a course for forthcoming research that is more vigorous, comprehensive, and dynamically associated with technological advancements.

In essence, this attention will focus on the importance of closing the existing gap through the use of interdisciplinary insights to develop better adaptive, personalized ITSs. This may have to be diverse enough to meet learners' needs through advanced AI technologies. The study calls for a research agenda that is of a global nature—a research agenda with the spirit of collaboration, innovation, and inclusivity of all to be able to realize the potential benefit of AI in education for all. In so doing, it purports to set a comprehensive roadmap for future research, poised to drive the field of educational technologies toward greater sophistication, relevance, and impact.

REFERENCES

[1]. 1. Bailón A, Fajardo W, Molina-Solana M. Intelligent tutoring system, based on video E-learning, for teaching artificial intelligence. Vol. 372, Advances in Intelligent Systems and Computing. 2015. p. 215–24.

[2]. 2. Francisco RE, Silva F de O. Intelligent Tutoring System for Computer Science Education and the Use of Artificial Intelligence: A Literature Review [Internet]. Vol. 1, International Conference on Computer Supported Education, CSEDU - Proceedings. 2022. p. 338–45. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85140902071&doi=10.5220%2f0011084400003182&partnerID=40&md5=e157c19128a9b9c376dc242ec3dc7881

[3]. 3. Putnam V, Conati C. Exploring the need for explainable artificial intelligence (XAI) in intelligent tutoring systems (ITS) [Internet]. Vol. 2327, CEUR Workshop Proceedings. 2019. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85063217310&partnerID=40&md5=df002f28e6c6395f790a5f15ec29c34c

[4]. 4. Clancey WJ, Hoffman RR. Methods and standards for research on explainable artificial intelligence: Lessons from intelligent tutoring systems [Internet]. Vol. 2, Applied AI Letters. 2021. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85177801933&doi=10.1002%2fail2.53&partnerID=40&md5=42539873ae603175adaa6a2abd9795c5

[5]. 5. Brent H, Roberts DL. A review of student modeling techniques in intelligent tutoring systems [Internet]. Vol. WS-12-17, AAAI Workshop - Technical Report. 2012. p. 61–6. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84876045003&partnerID=40&md5=645b3954227c8af1b5d5b6ad32e76932

[6]. 6. Dos Santos CT, Frozza R, Dhamer A, Gaspary LP. DÓRIS - pedagogical agent in intelligent tutoring systems. Vol. 2363, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 2002. p. 91–104.

[7]. 7. Sindi HF. A machine learning approach for intelligent tutoring systems. Vol. 4, WSEAS Transactions on Systems. 2005. p. 1053–7.

[8]. 8. Gembarski PC, Hoppe L. Considering Intelligent Tutoring Systems as Mass Customization of Digital Education. Lecture Notes in Mechanical Engineering. 2022. p. 935–42.

[9]. 9. Nakamura M, Iwane N, Otsuki S. Intelligent tutoring system for reading mathematical expressions. Vol. 31, Systems and Computers in Japan. 2000. p. 56–64.

[10]. 10. Ivanova TI. Component based development of ontology-based intelligent tutoring systems [Internet]. 2021 35th International Conference on Information Technologies, InfoTech 2021 - Proceedings. 2021. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85116708142&doi=10.1109%2fInfoTech52438.2021.9548621&partnerID=40&md5=d3780d8a6601a7488ab15660b6cf418f

[11]. 11. Ji S, Yuan T. Conversational Intelligent Tutoring Systems for Online Learning: What do Students and Tutors Say? [Internet]. Vols. 2022-March, IEEE Global Engineering Education Conference, EDUCON. 2022. p. 292–8. Available from: https://www.scopus.com/inward/record.uri

?eid=2-s2.0-85130431436&doi=10.1109%2fEDUCON52537.2022.9766567&partnerID=40&md5=a3d1d43862106a1e0cf3f47ec72273b9

[12]. 12. Guleria D, Kaur G. Bibliometric analysis of ecopreneurship using VOSviewer and RStudio Bibliometrix, 1989–2019. Library Hi Tech. 2021 Jan 1;39(4):1001–24.

[13]. 13. Niazi MA. Review of "CiteSpace: A Practical Guide For Mapping Scientific Literature" by Chaomei Chen. Complex Adaptive Systems Modeling. 2016 Oct 18;4(1):23.

[14]. 14. Thangavel P, Chandra B. Two Decades of M-Commerce Consumer Research: A Bibliometric Analysis Using R Biblioshiny. Sustainability. 2023 Aug 1;15(15):11835.

[15]. 15. Abbas AF, Jusoh A, Masod A, Ali J. A Bibliometric Analysis of Publications on Social Media Influencers Using Vosviewer. Journal of Theoretical and Applied Information Technology. 2021;99(23):5662–76.

[16]. 16. Alsharif AH, Salleh NZ, Baharun R. Research Trends of Neuromarketing: A Bibliometric Analysis. Journal of Theoretical and Applied Information Technology. 2005;98(15):2948–62.

[17]. 17. De Bruin RE, Braam RR, Moed HF. Bibliometric lines in the sand. Vol. 349, Nature. 1991. p. 559–62.

[18]. 18. Achuthan K, Nair VK, Kowalski R, Ramanathan S, Raman R. Cyberbullying research — Alignment to sustainable development and impact of COVID-19: Bibliometrics and science mapping analysis. Computers in Human Behavior. 2023 Mar;140:107566.

[19]. 19. Bales ME, Wright DN, Oxley PR, Wheeler TR. Bibliometric visualization and analysis software: State of the art, workflows, and best practices. 2020;

[20]. 20. Guo X. Urban tourism destination image: a bibliometric visualization review. K [Internet]. 2023 Aug 1 [cited 2023 Oct 8]; Available from: https://www.emerald.com/insight/content/doi/10.1108/K-04-2023-0646/full/html

[21]. 21. Komperda R. Likert-type survey data analysis with R and RStudio. Vol. 1260, ACS Symposium Series. 2017. p. 91–116.

[22]. 22. Racine JS. RStudio: a platform-independent IDE for R and Sweave. JSTOR; 2012.

[23]. 23. Salim N, Gopal K, Ayub A. Effects of using RStudio on statistics performance of Malaysian undergraduates. Malaysian Journal of Mathematical Sciences. 2019;13(3):419–37.

[24]. 24. McAllister JT, Lennertz L, Mojica ZA. Mapping A Discipline: A Guide to Using VOSviewer for Bibliometric and Visual Analysis. Science & Technology Libraries. 2022;41(3):319–48.

[25]. 25. Van Eck NJ, Waltman L. VOSviewer: A computer program for bibliometric mapping [Internet]. 12th International Conference on Scientometrics and Informetrics, ISSI 2009. 2009. p. 886–97. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84901992309&partnerID=40&md5=2b19eafa3759e96b197c3ec7535a731f

[26]. 26. Van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010 Aug;84(2):523–38.

[27]. 27. Yang J, Cheng C, Shen S, Yang S. Comparison of complex network analysis software: Citespace, SCI 2 and Gephi. In: 2017 IEEE 2nd International conference on Big data analysis (ICBDA). IEEE; 2017. p. 169–72.

[28]. 28. Zang X, Zhu Y, Zhong Y, Chu T. CiteSpace-Based Bibliometric Review of Pickup and Delivery Problem from 1995 to 2021 [Internet]. Vol. 12, Applied Sciences (Switzerland). 2022. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85130062492&doi=10.3390%2fapp12094607&partnerID=40&md5=9f9782fabfa2756d75a3f6bd29c1b991

[29]. 29. Badaracco M, Martínez L. An intelligent tutoring system architecture for competency-based learning. Vol. 6882 LNAI, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 2011. p. 124–33.

[30]. 30. Virvou M, Sidiropoulos SC. An intelligent tutoring system over a social network for mathematics learning [Internet]. IISA 2013 - 4th International

Conference on Information, Intelligence, Systems and Applications. 2013. p. 252–7. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84889049649&doi=10.1109%2fIISA.2013.6623723&partnerID=40&md5=8cbcdda146b959b2cf9fb6f344cdac34

[31]. 31. Lippert A, Shubeck K, Morgan B, Hampton A, Graesser A. Multiple Agent Designs in Conversational Intelligent Tutoring Systems. Vol. 25, Technology, Knowledge and Learning. 2020. p. 443–63.

[32]. 32. Huang J, Chen Z. The research and design of web-based intelligent tutoring system. Vol. 11, International Journal of Multimedia and Ubiquitous Engineering. 2016. p. 337–48.

[33]. 33. Yu Y, Wang JH. The study on the key technologies in multiple agent-based intelligent tutoring system. Vols. 846–847, Advanced Materials Research. 2014. p. 1889–92.

[34]. 34. Baas J, Schotten M, Plume A, Côté G, Karimi R. Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. Quantitative Science Studies. 2020 Feb 1;1(1):377–86.

[35]. 35. Gavel Y, Iselid L. Web of Science and Scopus: a journal title overlap study. Online information review. 2008;32(1):8–21.

[36]. 36. Harzing AW, Alakangas S. Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. Scientometrics. 2016;106:787–804.