Journal of Theoretical and Applied Information Technology
31st March 2024. Vol.102. No 6

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

TRANSFORMATIVE PEDAGOGIES: A BIBLIOMETRIC JOURNEY THROUGH ADAPTIVE LEARNING SYSTEMS

JOBIN JOSE [1], ALICE JOSEPH [2], PRATHEESH ABRAHAM [3], ROSHNA VARGHESE [4], BEENAMOLE T [5], SONY MARY VARGHESE [6], SUBY ELIZABETH OOMMEN [7]

[1] Librarian, Marian College Kuttikkanam Autonomous, Idukki, Kerala, India
[2] Associate Professor, St. Joseph College of Teacher Education for Women, Ernakulam, Kerala, India
[3]Assistant Professor, St. Thomas College of Teacher Education Pala, Kottayam, Kerala, India
[4] Assistant Professor, School of Management and Business Studies, Mahatma Gandhi University Kottayam, Kerala, India
[5] Librarian, Mar Ivanios College (Autonomous), Thiruvananthapuram, India
[6] Assistant Professor, Peet Memorial Training College, Mavelikara, Kerala, India
[7] Assistant Professor, Peet Memorial Training College, Mavelikara, Kerala, India

E-mail: [1] jobin.jose@mariancollege.org, [2] dralicejoseph@stjosephcte.in,[3] pratheesh@stcte.ac.in, [4]roshnavarghese@mgu.ac.in, [5] beenapanikker@gmail.com, [6] dr.sony@peetmemorialcollege.org, [7] suby.elizabeth@gmail.com

ABSTRACT

As a major shift in education technologies, Adaptive Learning Systems (ALS) use artificial intelligence and similar technologies, adapting the lessons to the needs of individual students. Emphasizing transformative pedagogy and teaching strategies that transform the learners' cognitive and interactive patterns, this study presents a comprehensive bibliometric analysis of ASL. Contrary to conventional teaching methods, ALS alters dramatically the way students think and interact with their environment. This research has utilized an all-inclusive bibliometric analysis to analyze the evolution, trends, and themes in ALS by using an extensive set of data from the Web of Science (WoS) and Scopus. The primary objective of Bibliometric analysis is to map the development of ALS in teaching and learning while marking the important trends, models, and thematic priorities. The relevance of this research lies in its comprehensive analysis of the Adaptive Learning Systems (ALS) field through bibliometric methods, offering critical insights into the trends, key contributors, and thematic developments over time. The systematic evaluation enables the appraisal of the impact created by major contributors like authors, organizations, journals, etc. The study also examines, using the advanced data collection technique, influential articles, and publications that enormously contributed to shaping ALS. Similarly, it does the rating effectively upon evaluating the mutual relationships among important terms, concepts, and factors through co-references and co-occurrences. It highlights the increasing scholarly output and identifies key contributors and influential works, underscoring the growing recognition of ALS's importance due to technological advancements. The study's findings on global research contributions, thematic analyses, and collaboration networks offer new insights into the field's dynamics, setting a foundation for future research directions. To visually represent bibliometric data, web analytic tools are used, explaining intricate relationships and thematic clusters. Identifying the unexplored areas and discussing the practical implications of ASL development, research, and analysis of combined data taken from WoS and Scopus provides a unique perspective. Consequently, researchers, educators, policymakers, etc., get valuable insights that enable advancing and understanding the area. This bibliometric analysis will undoubtedly guide future research in the area of transformative pedagogy as it is the most sought-after method in understanding the scholarly landscape of ALS

Keywords: *Adaptive Learning System, Bibliometric Analysis, R-Studio, Biblioshiny*

1. INTRODUCTION

An adaptive learning system, the most modern innovation in education technology, provides a customized learning experience and adapts itself to the individual needs of the student (1). While allowing customization of course materials to meet the individual needs of each learner, this

system assesses students' academic performance by using advanced logarithms as well (2). It means that personalization is the unique feature of this learning system, and it guarantees a thoughtfully adjusted course content and learning pace in order to suit individual needs and abilities while marking the area where modifications are required and identifying the personal interest of each student (3). This is how it provides an adaptive learning experience and regular feedback, enabling students to notice their academic progress and identify weaker areas where their focus is required. In this system of learning, the trajectory of learning is perfectly adjusted in accordance with the level of students' academic performance and engagement (4,5). It ensures that the challenges encountered are appropriate and achievable. By gathering in-depth data on students' performance, this system invariably generates analytics on learning trends and the effectiveness of learning content (6,7). While promoting student participation and motivation, this approach enormously caters to learners with diverse learning needs, and enhances accessibility and inclusivity within the educational domain. Such a utilization of learning resources allow educators and educational institutions to satisfy various learning deeds of their student population (8,9). In fact, the advent of Adaptive Learning System paved way to revolutionizing the conventional education system which, in the aftermath, turned to a more personalized, interactive, and knowledge- based education with significantly improved overall quality, efficacy and learning engagement (4). One of the unique features of Adaptive Learning System is the ability to provide immediate information and insight from data analysis. Students receive prompt feedback on their endeavors so that they get immediate recognition and correction of errors. The information collected in this system is of great value as it helps teachers to identify learning pattern, plan teaching method, predict learning outcome, and so on. Having acknowledged the learning potential of ALS in revolutionizing the conventional education system, various governments and academics across the word enthusiastically came forward to implement this system. Numerous studies vouch for the tremendous impact of Adaptive Learning System (ALS) and how it effectively enhances students' academic performance, heightens motivation, and improves self-efficiency (1,10).

Apart from this, it is worth noting that Adaptive Learning System (ALS) tackles equality issues effectively within the educational domain as it offers personalized assistance to students from various social backgrounds and with distinct learning preferences (11) . The present study explores the biometric domain of Adaptive Learning System (ALS), examining the scope of expansion and trends of scholarly research in this area. By analyzing public trends, author network, and co- occurrence, we aim to find out the primary focus area, new research trajectories, impactful and scholarly discourses surrounding Adaptive Learning System. Bibliometric study is expected to throw light on the status of the latest ALS research by revealing the priority area and possible knowledge gaps. As such, these data will certainly contribute to establishing effective means of implementing ALS with a vehement influence on future research programs as well. The analysis of ALS influence on instructional design, assessment method, and teachers' professional development, this study will reveal how this system is reshaping the responsibilities of educators and creating an educational setting where students' engagements and needs are the priority (2).

Bibliometrics analysis, quantitative assessment system, plays a crucial role in analyzing literature even when sophisticated technology rules the roost (12,13). The most effective method with powerful tools makes the system outstanding and it produces assessment results with optimum accuracy. As such, it will enable the researchers to arrive at a significant conclusion prior to determining the efficacy of the pattern, trend, connections, Co-occurrence, and logical order in any piece of academic literature anywhere in the world (14–17). To comprehend well the setup and the study field, Bibliographic information such as citations, publication date, author affiliations, keywords remain the pivotal factors (18–20). Moreover, Biometric Analysis is not only determining the authors' influence but also seeing the impact of journals in the field and tracking the research methods adopted to identify the emerging trends (21,22). This method helps the readers gather comprehensive details on the intellectual concept as well as the social structure in the related field. Likewise, they also draw information as to how those social structures underwent notable changes from time to time (23,24). The number of academic publications may increase but the

importance of Bibliometrics will remain the one and only reliable method for the scientific analysis and logical understanding while enhancing the efficacy of disseminating information.

A well-known software called Biblioshiny associated with the bibliometric R- package intended for analyzing and visualizing bibliographic data, offers a user- friendly online interface for carrying out effective bibliometric analysis without R- coding knowledge (25–27). Users could use the R- bibliometric package, employing a variety of indices and techniques, to analyze data from scientific publications to identify trends and insights. Hence biblionshiny streamlines the process with this instinctive interface over the bibliometric package (27–29).

From the previous studies, we have found out that the bibliometric analysis conducted so far has not yet combined data from both Web of Science and Scopus. Also, in the realm of academia and research, studies on the relevance of Adaptive Learning Systems have not yet been conducted so far. The Issues found in Knowledge Creation are Data Inconsistencies and Data Duplication. WoS and Scopus may have variations in their data coverage, citation counts, and indexing methods. These inconsistencies can lead to discrepancies in the results obtained from the two databases, impacting the reliability of the analysis. To remove the inconsistencies, we prepared the data. Duplicate records for the same publication across the two databases may cause inflating citation counts and inaccuracy of data. To avoid that we removed the duplicate records using PRISMA method.

The objectives of this analysis are

1. To identify the scientific research output of the topic Adaptive Learning System
2. To identify the most relevant journals and authors in this area of research.
3. To identify the geographical significance of ALS in research.
4. Detecting emerging themes and gaps in the literature.
5. Providing recommendations for future research.

2. LITERATURE REVIEW

Chen S., & Zhang J. (2008) examine the possibility of integrating Computerized Adaptive Testing (CAT) into an adaptive learning system to effectively evaluate learner's ability level. They discuss the method of this integration and analyze the algorithms based on item response theory and the three- parameters logistic model. While CAT is designed to update the learners' ability level in the student model, it permits the system to support personalized learning through adaptive content and navigation. This study also facilitates understanding the mechanism of adaptive testing in learning systems and the impact on personalizing learning experience (3).

Jia, B., Y., & Zhang, J. (2012) addresses the noticeable challenges in learner modeling within adaptive learning systems, and exposes issues such as unscientific attention dimensions and ineffective representation methods. The authors in their reports come out with a new learner model with focus on three major characteristics i.e. knowledge level, cognitive ability, and preference. Based on the experiment result, they validated the model's effectiveness in source organisation and learning path optimisation while showcasing the practical utility in adaptive learning (8).

Ding, Zhu, and Guo, in their study (2018), introduce a novel learner model exclusively designed for Adaptive learning systems with an emphasis on four fundamental factors such as basic information, learning style, knowledge level and cognitive ability. The study further explores techniques for initialising and modifying these characteristics, highlighting the comprehensive approach of the model that offers unique benefits in online education and improves the effectiveness of adaptive learning systems. They demonstrated this model's practical usability and validity by implementing it on the Moodle platform (4).

Shao X. (2022) explores personalized recommendation technology in adaptive learning systems through a specific case study of a Java programming course. In their research, they incorporate an algorithm for collaborative filtering recommendation to create a personal adaptive learning question bank system, ensuring improved learning efficiency and academic achievement. This study also shows how the practical application of personalised recommendation is used in adaptive learning

systems. In addition, it serves as a highly reliable reference for other adaptive learning systems that use personalised recommendations (5).

Haug J., Fisher D., & Hagel D. (2023) introduce a version of the compact learning style questionnaire index appropriate for adaptive learning systems in higher education. Their study pinpoints the necessity of accurately identifying individual learning preferences and styles, which is essential for user-centric adaptive learning. Essentially, this study focuses on the necessity for practical tools to remember students' learning preferences in adaptive learning systems, which could solve the cold start problem. The proposed abridged version of the questionnaire, supported by statistical analysis, is the paradigm of a notable advancement in enhancing learner-benefiting in adaptive systems (30).

Huang Y., Fan Y., Zhuang Z., & Tong M. (2023) present a dynamic model for adaptive learning systems that combines system dynamics and inverse control theory. They focus more on the analysis of the fundamental principles and operational mechanisms. They use system identification methods and adaptive filters to model learners and learning strategists. This study, beyond doubt, presents an innovative method for comprehending the functional mechanisms of adaptive learning systems, illustrating the theoretical base of their design and advancement (10).

3. MATERIALS AND METHODS USED

The relevant scholarly papers pertinent to the analysis were retrieved from the core collections of WoS and Scopus databases. On November 22, 2023, we searched using keywords like "Adaptive Learning System". The data comprised conference papers, Book chapters, and articles from peer-reviewed journals. The search was performed without regard to language restrictions. We extracted 833 documents between 1969 and 2023 from 501 distinct sources from Scopus, as shown in Table 1. Similarly, we retrieved 82 papers between 1997 and 2023 from 54 different Web of Science core collection sources, as shown in Table 1. The two data sources were combined using RStudio, which helped us remove any duplicates resulting after the merge operation. Eighty-one duplicates were detected. A total of 834 articles were chosen for study after the elimination process. The results were saved as an "excel" file, and we performed a bibliometric analysis of the information using Biblioshiny. Table 3 provides detailed information regarding the primary components and aspects of the study.

Table 1: Crucial Elements of the Research from Web of Science

Description	Results
Query	TITLE-ABS-KEY ("Adaptive Learning System") AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE , "ch"))
MAIN INFORMATION ABOUT DATA	
Timespan	1969:2024
Sources (Journals, Books, etc)	501
Documents	833
Authors	2046
DOCUMENT TYPES	
article	287
book chapter	39
conference paper	507

Table 2: Crucial Elements of the Research from Scopus

Description	Results
Query	"adaptive learning system" (Topic) and Article or Proceeding Paper or Early Access (Document Types)
MAIN INFORMATION ABOUT DATA	
Timespan	1997:2023
Sources (Journals, Books, etc)	54
Documents	82
Authors	267
DOCUMENT TYPES	
article	74
article; early access	3
article; proceedings paper	5

Table 3: Research facets from Web of Science and Scopus

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1969:2024
Sources (Journals, Books, etc)	503
Documents	834
Annual Growth Rate %	1.27
Document Average Age	8.06
Average citations per doc	9.215
References	20295
DOCUMENT CONTENTS	
Keywords Plus (ID)	3514
Author's Keywords (DE)	1891
AUTHORS	
Authors	1964
Authors of single-authored docs	82
AUTHORS COLLABORATION	
Single-authored docs	93
Co-Authors per Doc	3.28
International co-authorships %	0.1199
DOCUMENT TYPES	
article	288
article; early access	1
article; proceedings paper	2
book chapter	38
conference paper	505

4. RESULTS

4.1 Annual Scientific Production

Figure 1 depicts the annual scientific article production trend from 1969 to 2023. Initially, from 1969 to the early 2000s, the production of scientific articles was relatively stable and low, indicating a consistent level of scientific research output during this period. However, starting in the early 2000s, there was a noticeable increase in the number of articles produced, suggesting an expansion in scientific research, possibly due to increased funding, the emergence of new research fields, the rise of digital publishing, or a combination of these factors. A dramatic peak in article production has been observed in recent years, particularly in 2022, which might reflect a surge in research, perhaps in response to global events such as the COVID-19 pandemic or other significant scientific developments. Notably, there is a sudden decline in the number of articles in 2023, which could be attributed to incomplete data collection if the year has yet to conclude, or it may represent a natural decrease in scientific output.

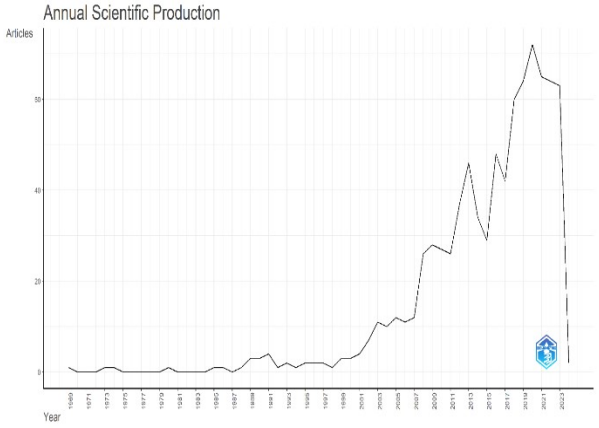

Figure 1: Annual scientific article production from 1969 to 2023

4.2 Most Relevant Sources

Most Relevant Sources provides insight into the document distribution across various scholarly sources. The most prominent source, "Lecture Notes in Computer Science," stands out with 64 documents, suggesting it is a primary publication venue in this dataset. "Advances in Intelligent Systems and Computing" and "ACM International Conference Proceeding Series" follow with 23 and 20 documents, respectively, indicating their significant but lesser contribution than the leading source. A gradual decline in document numbers is observed among other sources, such as "CEUR Workshop Proceedings" and "Communications in Computer and Information Science," implying these sources are relevant but not as dominant. The least represented sources, "Computers and Education" and "Applied Mechanics and Materials," with 6 to 8 documents, may suggest they are niche or emerging venues in this research field.

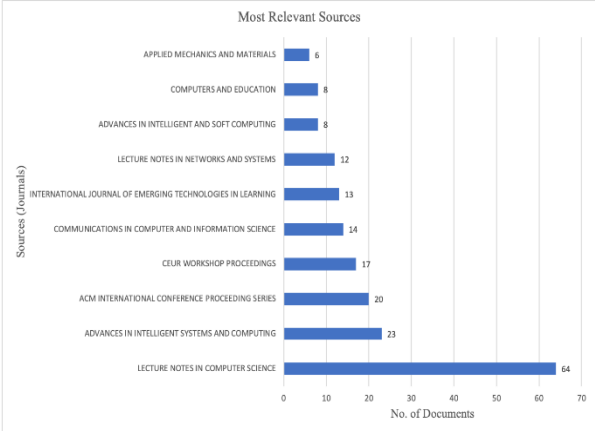

Figure 2: Most Relevant Sources

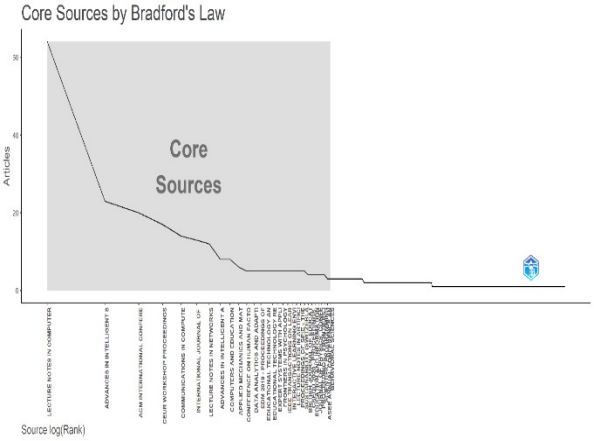

Figure 3: Core Sources by Bradford's Law

4.3 Core Sources by Bradford's Law

Figure 3 depicts a representation of Bradford's Law through a graphical plot showing the distribution of scientific articles across various sources. The law suggests that a core group of journals yields the most articles on a specific subject, evident from the highlighted area labeled "Core Sources." The steep decline from this core group on the graph indicates that a few journals publish many articles, while a much larger number of journals publish progressively fewer articles each. The y-axis denotes the number of articles, and the x-axis, using a logarithmic scale for ranks, illustrates the diminishing frequency of articles as one moves away from the core sources. "Lecture Notes in Computer Science" stands out as the top source, with others like "Advances in Intelligent Systems and Computing" following suit, demonstrating the central role these publications play in their respective fields. The flattening curve towards the right end of the graph exemplifies the long tail of Bradford's Law, where numerous sources contribute minimal articles, highlighting the concentration of relevant literature in a few key sources.

4.4 Most Relevant Authors

Most Relevant Authors visualises the number of documents attributed to each author, providing insight into their relative contribution and prominence within the research field. The chart identifies "VITTORINI P" as the most prolific author with 19 documents, followed by "DI M T" with 18, suggesting these individuals are significant figures in their domain. A tier of authors, including "GENNARI R," "CHEN S," and others, contribute between 7 to 11 documents, indicating a robust activity level. Those authors represented with the most miniature bubbles, such as "HWANG G" and "ZHANG J," with 7 to 8 documents, while contributing fewer works, are still notable within the dataset.

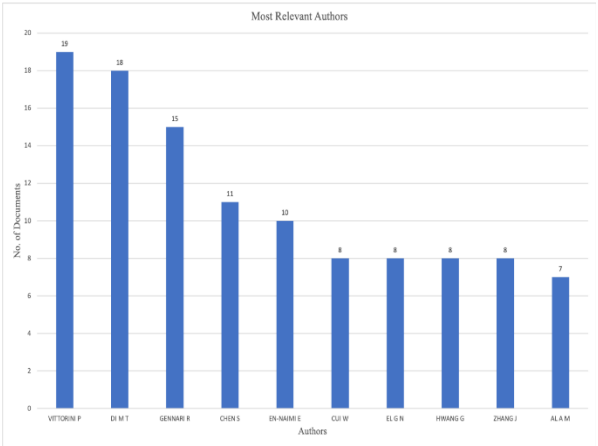

Figure 5: Most Relevant Authors

4.5. Countries' Scientific Production

Table 4 reveals that China leads in a specific measure with a frequency of 149, followed by the USA at 127, indicating their dominant

positions in producing scientific publications on Adaptive Learning Systems. Countries like Morocco, Italy, and Germany also have significant, though lower, frequencies, showcasing a global spread in the measured aspect.

Table 4 Countries' Scientific Production

No.	Region	Freq.
1	China	149
2	USA	127
3	Morocco	52
4	Italy	40
5	Germany	35
6	India	28
7	UK	25
8	Indonesia	20
9	Canada	18
10	South Korea	18

4.6. Most globally cited documents

Most Global Cited Documents provide a comprehensive view of scholarly paper impact, with columns detailing each paper's title, Digital Object Identifier (DOI), total citations, annual average citations, and normalised total citations. Total citations reflect a paper's overall influence in its field, while the yearly citation rate indicates its ongoing relevance. Including a 'Normalised TC' column suggests an effort to compare papers across different fields and publication years. This dataset is a crucial resource for bibliometric analysis, highlighting various disciplines' most influential academic papers.

Table 5: Most globally cited documents

No.	Paper	DOI	Total Citations	TC / Year	Normalised TC
1	Truong HM, 2016, Comput Hum Behav	10.1016/J.Chb.2015.02.014	317	39.63	19.99
2	Tseng JCR, 2008, Comput Educ	10.1016/J.Compedu.2007.08.002	239	14.94	10.15
3	Bull S, 2007, Int J Artif Intell Educ	NA	217	12.76	7.13
4	Mccormack MD, 1993,	10.1190/1.1443352	166	5.35	1.98
5	Yang T-C, 2013, Educational Technology and Society	NA	147	13.36	8.64
6	Shute VJ, 2012, Adaptive Technologies for Train and Education	10.1017/CBO9781139049580.004	137	11.42	11
7	Sinclair AJ, 2008, Environ Impact Assess Rev	10.1016/J.Eiar.2007.11.001	130	8.13	5.52
8	Afini Normadhi NB, 2019, Comput Educ	10.1016/J.Compedu.2018.11.005	98	19.6	9.91
9	Kabudi T, 2021, Comput Educ	10.1016/J.Caeai.2021.100017	94	31.33	22.3
10	Roberts-Mahoney H, 2016, J Educ Policy	10.1080/02680939.2015.1132774	93	11.63	5.87

4.7. Reference Spectroscopy

Figure 7 depicts the reference spectroscopy over time. The black line represents the total number of cited references, while the red line indicates the deviation from the five-year median. The graph reveals a steady increase in the number of references included in documents in the dataset. 1703, there were only eight reference publications, but by 1736, this number had skyrocketed to 2,821, representing an increase of over 35,000%. The red line highlights a recent

divergence from the five-year median, suggesting rapid growth in the Adaptive Learning System and related fields and a surge of published new research.

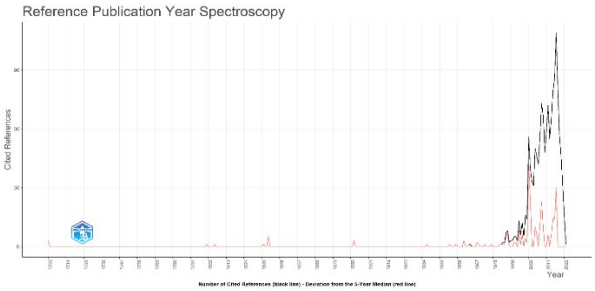

Figure 6: Reference Spectroscopy

4.8. Trend topics

The trending topics from 2002 to 2022 include machine learning, natural language processing systems, learning models, deep learning, automatic identification, experience, education, computational intelligence, artificial intelligence, personalised learning systems, and adaptive learning. The image depicts a line graph illustrating the fluctuating popularity of different subjects throughout recent years. The trend topics graph indicates a consistent upward trajectory in the popularity of particular subjects in recent years. This is attributed to various factors, including the ubiquity of technology, widespread social media use, and fast-growing technological advancement. The frequency of media learning has experienced a significant increase in recent times, as does the term frequency of the topic neural network. The recent rise in this subject's popularity is attributed to the advancement of artificial intelligence (AI) and machine learning technologies. The more the significance of individual learning styles and the need for effective teaching techniques are recognized, the faster those subjects gain popularity. The term Frequency of the Topic Intelligent's popularity continues to grow as fast as the demand for personal adaptive learning experiences does. The statistical study indicates a rising demand for an educational system that recognises individual needs and offers customized learning experiences.

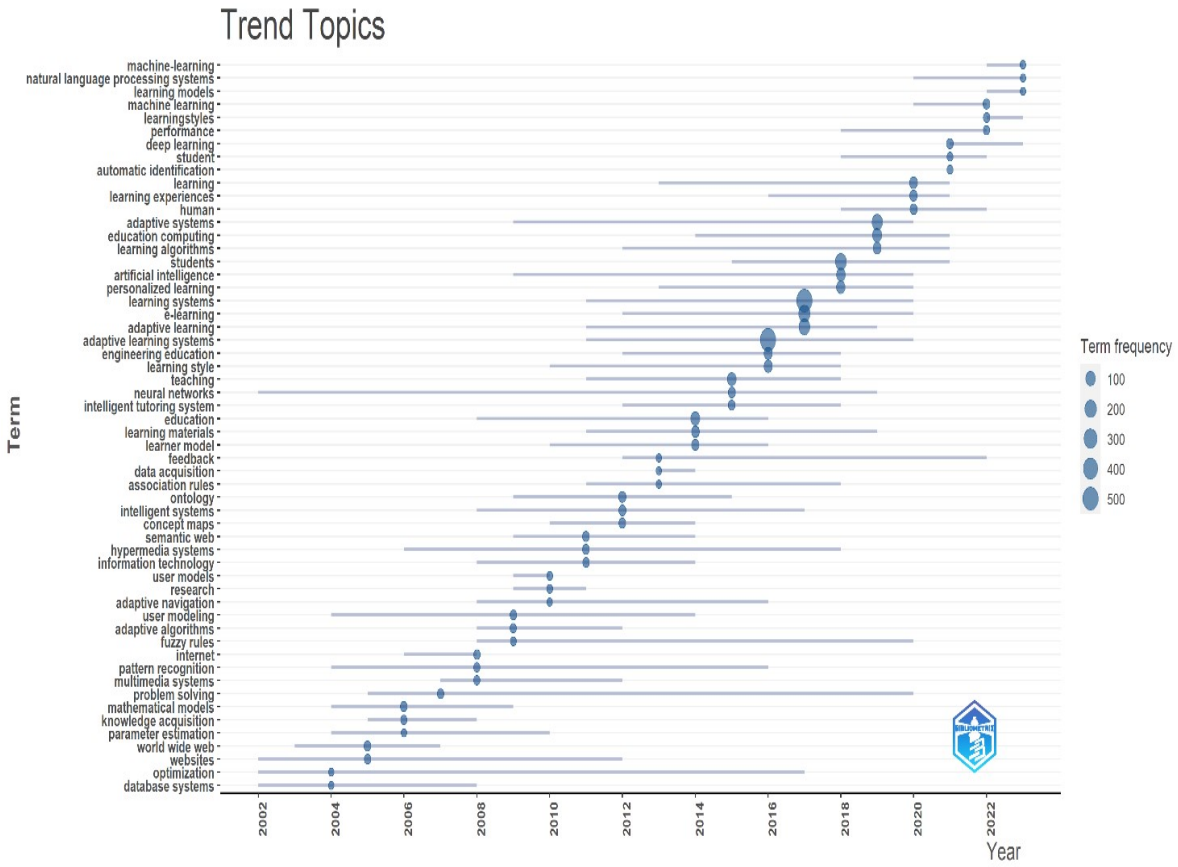

Figure 8: A visual indicating the popularity of Topics

4.9. Thematic Map

Thematic map, the analytical tool, is meticulously divided into four quadrants with a horizontal axis measuring the relevance or centrality of the themes and a vertical axis gauging their development or density, categorising the theme based on centrality and development within the research area. The top right quadrant, labelled motor themes, remains with no entries but typically compromises well-developed central themes driving the field. Meanwhile, the top left niche themes include less major yet well-developed topics like learning humans and articles. However, the bottom left quadrant indicates emerging or declining themes, suggesting the absence of new themes or the presence of one phasing out at the time of this analysis. Finally, the "Basic Themes" in the bottom-right corner contain foundational topics such as "education," "teaching," and "learning algorithms," which are essential to the field but not at the cutting edge of development. Central to the map are "learning systems," "adaptive learning systems," and "e-learning," signifying their current relevance and moderate development within the field.

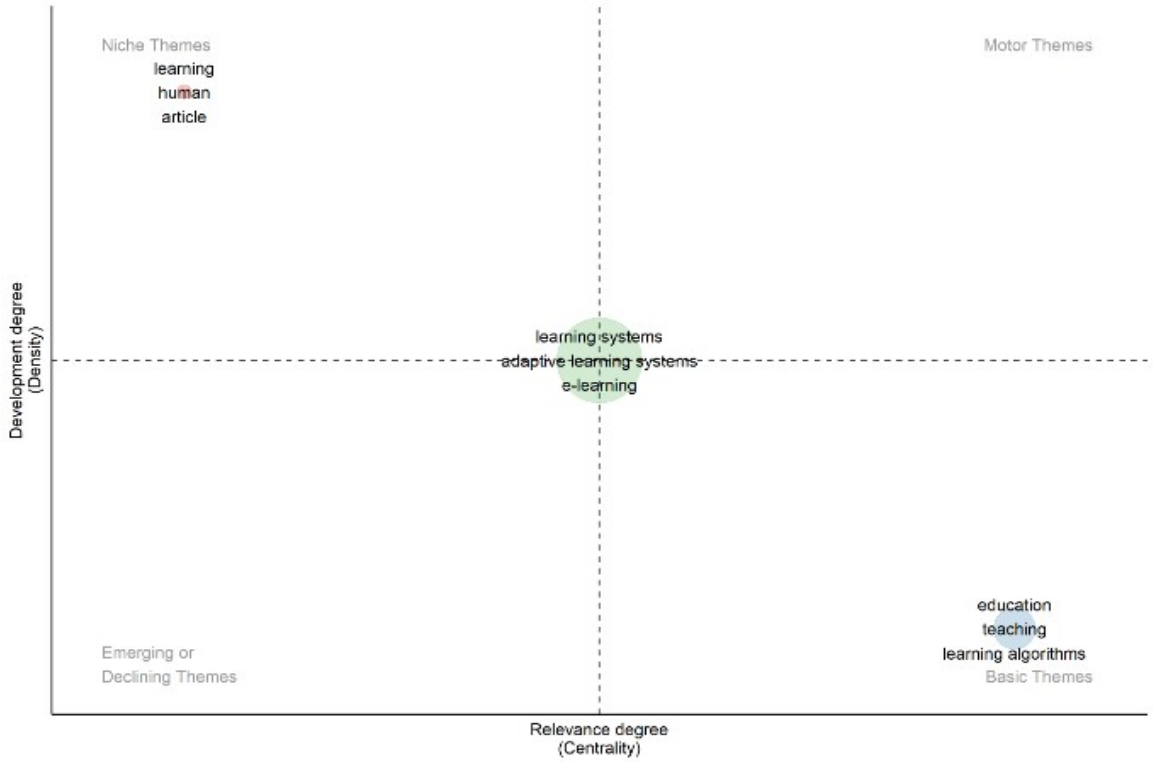

Figure 10 Thematic Representation of Keywords

4.9. Co-occurrence Network

Co-occurrence Network Analysis presents a co-word network analysis, used to examine concepts' interrelations and prominence in a specific area of study. It organises these concepts into nodes and assigns them to thematic groupings clusters. The 'Betweenness' centrality metric indicates the extent to which a node acts as a bridge within the network, while 'Closeness' measures the average shortest path to all other nodes, reflecting the node's accessibility. The 'PageRank' value estimates the node's influence. Figure 11 presents the high score of the terminologies such as ‘learning system’ and ‘adaptive learning system’ across these metrics and makes the terms central and influential within the framework. This indicates that around these key factors, other significant terms like ‘learning’ and ‘human ‘are interconnected, representing well-established research topics within the field, whereas ‘human’ depicts a high centrality hinting at its role in linking different themes within the network despite a lower page rank.

Journal of Theoretical and Applied Information Technology
31st March 2024. Vol.102. No 6

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

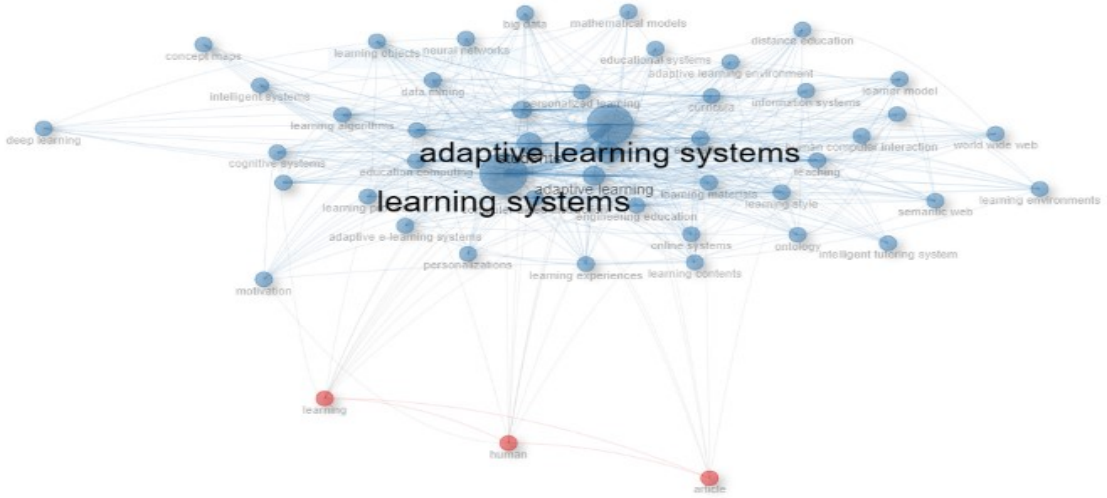

Figure 11 Co-occurrence clusters in Adaptive Learning Systems

4.10. Factorial Analysis

Figure 12 reveals the result of a factorial analysis on a set of specific terms from a co-word network, a method employed to comprehend the structure and pattern of a term within a particular domain. Similarly, terms including learning system, adaptive learning system, e-learning students, and adaptive learning are associated with scores across two dimensions (Dim. 1 & Dim. 2) and are put into different clusters with all cited terms belonging to cluster 1 upon classification. The negative score on Dim 1 suggests an inverse relationship among these terms and represents the underlying factors. In contrast, the scores on Dim.2, particularly for "e-learning" and "students," are higher, indicating a closer or more direct relationship with the factor represented by Dim.2. This dimension may capture different features or characteristics. At the same time, research is conducted, with cluster 1 likely delineating thematic grouping that shares standard features being highlighted by factorial analysis. This type of analysis is instrumental in converting complex data into interpretable patterns, suggesting how such datasets would be interconnected or complementary to different factors of academic discourses.

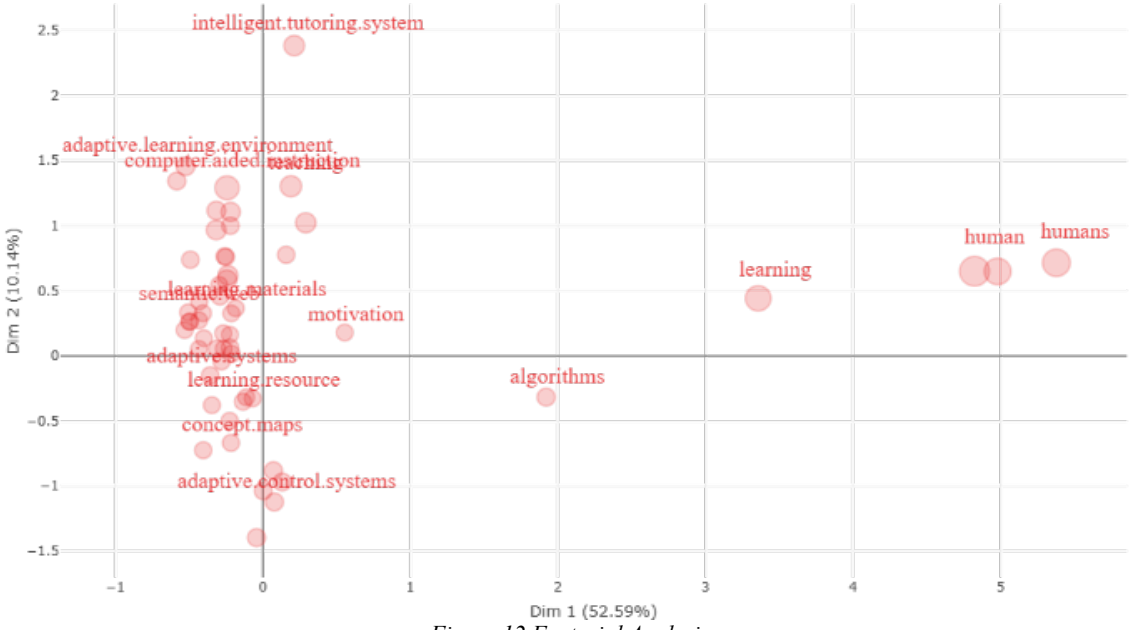

Figure 12 Factorial Analysis

4.10 Author Collaboration Network

Figure 13 shows a social network analysis focusing on the authors' collaborative interaction. Each mode that represents authors or researchers is identified by name, i.e. Chen S., Zhang J., and Bai S. The dataset is classified and arranged to various vital metrics: Cluster indicates the classification of the nodes and suggests groups or patterns of collaboration. 'Betwixtness' measures the extent to which a node acts as a connector in the network, with Zhang J., displaying a higher score and indicates a significant role in connecting various collaborators. Nearness indicates the distance of nodes to all others, with Zhang J. repeatedly scoring the highest, indicating a central position in the network, and PageRank hints at the importance or influence of the node, with Chen S., with a high score, proposing a strong presence in the collaborative domain. This structure and the score hint at the fact that nodes like Zhang J. and Chen S. are the critical factors in the network, with Zhang J standing as a chief connector and Chen S possessing substantial influence or centrality. An analysis of this kind is vital in comprehending the dynamic of collaboration within a specific domain or organisation, supplying insights regarding the flow of information and the structure of collaborative effort, as well as the way they are maintained.

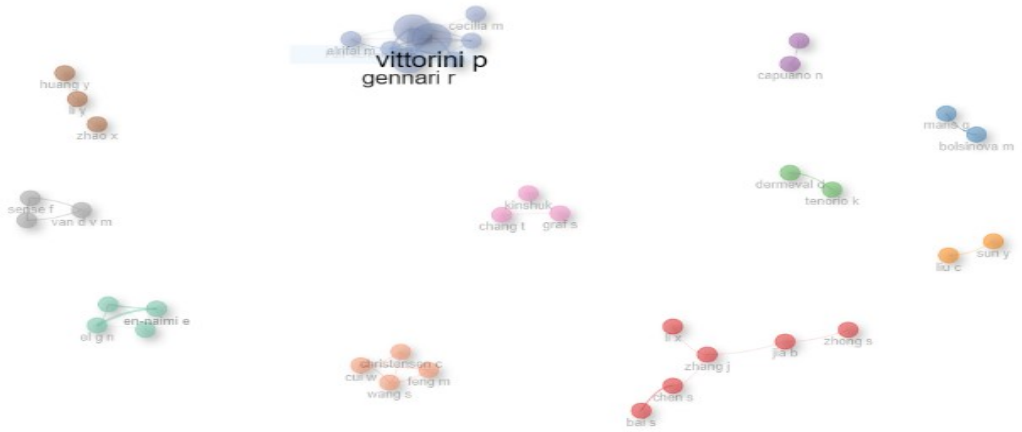

Figure 13 Collaboration of Authors

5. FINDINGS AND DISCUSSION

Scholarly papers on Adaptive Learning System were gathered from WoS and Scopus databases, amounting to 834 unique documents for study after duplicates were removed. From 1969 to the early 2000s, the production of scientific articles remained stable and low. However, a significant increase began in the early 2000s, peaking dramatically in 2022, possibly due to increased funding, new research fields, and digital publishing. The sudden decline in article production in 2023 could be due to incomplete data for the year or an actual decrease in scientific output. The visual analysis of document distribution highlights "Lecture Notes in Computer Science" as the most prominent source in the dataset, followed by sources like "Advances in Intelligent Systems and Computing" and "ACM International Conference Proceeding Series," with a notable decline in document numbers among less dominant sources, suggesting a varied level of relevance and focus in publication venues within this research field.

The graphical representation of Bradford's Law in the study shows that a small number of core journals, like "Lecture Notes in Computer Science," publish the majority of articles in a field, with a steep decline in article frequency among a larger number of journals, demonstrating the concentration of significant research in a few key sources. The visualisation of the Most Relevant Authors, "Vittorini P." and "Di M T" as the most prolific contributors, with a secondary tier of authors like "Gennari R." and "Chen S." also showing robust activity, indicating the varying levels of influence and contribution among authors in the research field. The data on Countries' Scientific Production reveals China as the leading contributor with 149 publications, followed by the USA, Morocco, Italy, and Germany, showing a diverse geographical distribution in scientific output, with notable contributions from countries across different continents. Most Globally Cited

Documents highlight the significant impact of specific papers in the field, with "Truong H M, 2016, Comput Hum Behav" leading in total citations and a range of other influential works, demonstrating the varied yet impactful contributions across years and topics in this academic domain.

The Reference Spectroscopy graph shows a dramatic increase in reference publications in spectroscopy over time, with a notable surge from just eight in 1703 to 2,821 in 1736 and a recent deviation from the five-year median, indicating rapid growth and new research in the field. The Trend Topics graph from 2002 to 2022 shows a growing popularity in fields like machine learning, natural language processing, and adaptive learning, likely driven by advancements in technology, social media, and a recognition of the need for personalised education methods and intelligent tutoring systems. The Thematic Map categorises themes in a research field by centrality and development, showing a lack of "Motor Themes" and "Emerging or Declining Themes" while identifying "Niche Themes" like "learning" and foundational "Basic Themes" such as "education," with "learning systems" and "adaptive learning systems" being central and moderately developed. The Co-occurrence Network Analysis indicates that terms like "learning systems" and "adaptive learning systems" are prominent and influential in the research network, with high scores in centrality metrics, while terms like "human" play a pivotal role in connecting various themes, showcasing the interconnectedness and significance of these concepts within the field. The Factorial Analysis of terms in a co-word network, including "learning systems" and "adaptive learning systems," reveals different relationships and thematic groupings along two dimensions, indicating how these terms are interconnected and contribute to various aspects of the research field. The author collaboration network analysis suggests the centrality of authors like Zhang J. and Chen S. in the collaborative web of authors, with Zhang J. being a critical connector and Chen S. a significant influencer, denoting the structure and dynamics of collaboration within the field.

We have done a comprehensive analysis by including both quantitative (publication counts, citation analysis) and qualitative metrics (e.g., thematic analysis, trend identification) which permits us to explore the ALS research landscape more effectively. The criteria selected for analysis are significant as it identifies the research gaps, emerging trends, and future directions for ALS which is crucial for guiding subsequent research. The different criteria include

1. Publication Volume Over Time: This allows for the assessment of interest and growth in ALS research.
2. Key Contributors: It allows to identification the leading authors, institutions, and countries which helps to pinpoint centers of excellence and collaborative networks, offering insights into the structure and dissemination of knowledge within the domain.
3. Thematic Trends: It uncovers the shifts in focus areas, emerging technologies, and application domains within ALS.

6. RESEARCH GAPS

The identified research gaps in "adaptive learning systems," determined through trend topics and thematic map analyses, encompass multiple crucial domains. Firstly, there needs to be a considerable disparity in incorporating emerging technologies like artificial intelligence, machine learning, and neural networks into adaptive learning systems. This integration is essential for improving the customisation and flexibility in educational experiences. Furthermore, despite the growing acknowledgement of various learning styles, there seems to be a lack of research on how adaptive learning systems can adequately address these differences, guaranteeing individualised and pragmatic education for diverse learners. Thirdly, the absence of "Motor Themes" in the thematic map suggests a lack of groundbreaking research in the field, indicating a need for innovative studies that could significantly advance adaptive learning.

One of the quadrants, emerging or declining, precisely points out the gap in exploring new areas of adaptive learning systems and comprehending the development of available methods. It also shows that the probable research opportunities may be integrated with fundamental educational themes to improve their efficacy. Similarly, the increasing acceptance of intelligent tutoring and personalized learning all across the world underscores a growing demand for such systems. However, studies in effectively designing and implementing these systems and meeting diverse learners' needs seem insufficient. It is recommended that a multidisciplinary approach with integrated technological advancements and updated educational theories address the issues in this area, focusing on individual learning preferences and

fostering innovative, improved adaptive learning systems.

7. PRACTICAL IMPLICATIONS

It provides educators and instructors vital insights into the evolution and efficacy of Adaptive Learning Systems, aiding in integrating these technologies into curricula. The responsibility for taking further steps on the researchers' findings and leveraging the implementation process primarily lies on policymakers and educational administrators. By effectively utilising their freedom and liberty in the process of decision-making about policies and investments, they could also design suitable policies for technology adoption in the educational setting. An overview of the key trends with well-defined gaps and emerging research areas, presented to leading academicians and researchers, could foster interdisciplinary collaboration. Using these insights effectively, technology developers could design user-friendly and inclusive products that align more closely with the education sector's needs. Undoubtedly, these advancements bring about enhanced, highly personalised learning experiences, and learners will enormously benefit from these as well. The study contributes to global education trends on a broader scale by highlighting the potential of adaptive learning systems in meeting diverse educational needs and promoting a more inclusive and equitable approach to education. In short, the study is a crucial resource in shaping educational practice, policies and technological advancements in adaptive learning.

8. CONCLUSION

The analysis we conducted highlights the Adaptive Learning Systems' scholarly landscape over several decades. Through the analysis, we were able to identify the key publication venues and the influential contributors. Our findings reveal a global interest in ALS, with notable research output from countries like China and USA. The thematic analysis—through spectroscopic graphs, trend analyses, and co-occurrence networks—highlights the field's dynamic nature, showing rapid advancements in areas like machine learning and personalized education. This study not only charts the historical development and current state of ALS research but also sets a base for future exploration in the domain. The steady growth in publication from the early 2000s to 2022 reflects the increasing recognition and importance of adaptive learning systems driven by technological advancement and increased digital publishing in the educational sector. Prominent sources like Lecture Notes in Computer science and notable contributions by specific authors like Vittorini P. and Di M T. indicate the concentration of research within specific journals, highlighting the central nodes of knowledge in this field. Spectroscopic graphs and trend analysis reinforce this assumption and demonstrate a dynamic and evolving research landscape that shows fast-growing progress in machine learning, natural language processing, and personalised education methods. The co-occurrence network and thematic map analysis demonstrate a more profound comprehension of the relationships among different concepts in the field. On the contrary, the factorial and author collaboration network analysis uncovers the complex dynamics of scholarly partnership and thematic groupings. The study marks significant research gaps, particularly in integrating new technologies and adapting systems to diverse learning styles, pinpointing areas for future research and development. Generally, bibliometric analysis sets the stage for future advancements and applications in the field. It also charts the historical trajectory of the current research in adaptive learning systems while potentially revolutionising educational practices and outcomes.

REFERENCES

[1] Li Q, Zhong S, Wang P, Guo X, Quan X. Learner model in adaptive learning system. Vol. 7, Journal of Information and Computational Science. 2010. p. 1137–45.

[2] Chen SM, Sue PJ. Constructing concept maps for adaptive learning systems based on data mining techniques. Vol. 40, Expert Systems with Applications. 2013. p. 2746–55.

[3] Chen S, Zhang J. Ability Assessment based on CAT in Adaptive Learning System [Internet]. Vol. 1, 2008 International Workshop on Education Technology and Training and 2008 International Workshop on Geoscience and Remote Sensing, ETT and GRS 2008. 2008. p. 88–91. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-70350675431&doi=10.1109%2fETTandGRS.2008.151&partnerID=40&md5=ac44b2b3a0676993be2b6d0bc68eb2a1

[4] DIng W, Zhu Z, Guo Q. A New Learner Model in Adaptive Learning System [Internet]. 2018 3rd International Conference on Computer and Communication Systems,

ICCCS 2018. 2018. p. 472–6. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85054790491&doi=10.1109%2fCCOMS.2018.8463316&partnerID=40&md5=a523618f93c6986a231adc30ab138d4a

[5] Zhao X. Research on Application of Personalized Recommendation Technology in Adaptive Learning System Based on Java Programming [Internet]. 2022 International Conference on Automation, Robotics and Computer Engineering, ICARCE 2022. 2022. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85149437417&doi=10.1109%2fICARCE55724.2022.10046617&partnerID=40&md5=4ea0b39f09cdd6ad82d4945fa2135370

[6] Ge Z, Xi M, Li Y. A literature review of the adaptive algorithms adopted in adaptive learning systems [Internet]. 2019 IEEE 4th International Conference on Signal and Image Processing, ICSIP 2019. 2019. p. 254–8. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85074433214&doi=10.1109%2fSIPROCESS.2019.8868893&partnerID=40&md5=d3afd2512d8384631f04359c4c5d13d6

[7] Zhao L, Wang H. Research on adaptive learning system based on three core modules [Internet]. Proceedings - 10th International Conference on Information Technology in Medicine and Education, ITME 2019. 2019. p. 447–52. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85079329372&doi=10.1109%2fITME.2019.00106&partnerID=40&md5=890e9e71f00383a3403d42b46c7dcfce

[8] Jia B, Yang Y, Zhang J. Study on learner modeling in adaptive learning system. Vol. 7, Journal of Computers (Finland). 2012. p. 2585–92.

[9] Voronina A, Shabalina O, Kataev A, Sadovnikova N. User Engagement Assessment for Adaptive Learning Systems. Vol. 1448 CCIS, Communications in Computer and Information Science. 2021. p. 545–58.

[10] Huang Y, Fan Y, Zhuang Z, Tong M. The Research on Dynamical Model of Adaptive Learning System [Internet]. Proceedings - 2023 5th International Conference on Computer Science and Technologies in Education, CSTE 2023. 2023. p. 56–60. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85174582631&doi=10.1109%2fCSTE59648.2023.00017&partnerID=40&md5=eb1b7758f384887437ddf2f67ff06a2a

[11] Upadhyay K, Kumar A, Gupta N. An Adaptive Recommender System Framework for Personalized E-Learning [Internet]. International Conference on Artificial Intelligence and Data Engineering, AIDE 2022. 2022. p. 19–22. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85150680889&doi=10.1109%2fAIDE57180.2022.10059869&partnerID=40&md5=e4919613753ec11b343cfa9c330cf259

[12] 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.

[13] Babu S, Thomas B. Bibliometric Analysis and Visualization of Scientific Literature on Random Forest Regression. Scientific Visualization. 2022;14(5).

[14] Antonio MS, Rusydiana AS, Laila N, Hidayat YR, Marlina L. Halal Value Chain: A Bibliometric Review Using R. Vol. 2020, Library Philosophy and Practice. 2020. p. 1–25.

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

[16] do Carmo G, Felizardo LF, de Castro Alcântara V, da Silva CA, do Prado JW. The impact of Jürgen Habermas's scientific production: a scientometric review. Scientometrics. 2023 Mar 1;128(3):1853–75.

[17] Tomaszewski R. Visibility, impact, and applications of bibliometric software tools through citation analysis. Scientometrics. 2023 Jul 1;128(7):4007–28.

[18] Chen Y, Dong Y, Zeng Y, Yang X, Shen J, Zheng L, et al. Mapping of diseases from clinical medicine research—a visualization study. Scientometrics. 2020 Oct 1;125(1):171–85.

[19] Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research. 2021 Sep 1;133:285–96.

[20] Godin B. On the origins of bibliometrics. Scientometrics. 2006 Jul;68(1):109–33.
[21] Ellegaard O, Wallin JA. The bibliometric analysis of scholarly production: How great is the impact? Scientometrics. 2015 Dec;105(3):1809–31.
[22] van Eck NJ, Waltman L. Visualizing Bibliometric Networks. In: Ding Y, Rousseau R, Wolfram D, editors. Measuring Scholarly Impact: Methods and Practice [Internet]. Cham: Springer International Publishing; 2014. p. 285–320. Available from: https://doi.org/10.1007/978-3-319-10377-8_13
[23] Alarcon-Ruiz CA, Maguiña JL, Apolaya-Segura M, Carhuapoma-Yance M, Aranda-Ventrura J, Herrera-Añazco P. Bibliometric Analysis of Medicinal Plants' Original Articles from Latin America and the Caribbean Region. J Scientometric Res. 2023 Apr 17;12(1):79–91.
[24] Cobo MJ, Martínez MA, Gutiérrez-Salcedo M, Fujita H, Herrera-Viedma E. 25years at Knowledge-Based Systems: A bibliometric analysis. Knowledge-Based Systems. 2015 May 1;80:3–13.
[25] Racine JS. RStudio: a platform-independent IDE for R and Sweave. JSTOR; 2012.
[26] 26. Racine JS. RSTUDIO: A platform-independent IDE for R and sweave. Vol. 27, Journal of Applied Econometrics. 2012. p. 167–72.
[27] Souza de Cursi E. Some Tips to Use R and RStudio. In: Souza de Cursi E, editor. Uncertainty Quantification using R [Internet]. Cham: Springer International Publishing; 2023. p. 1–108. Available from: https://doi.org/10.1007/978-3-031-17785-9_1
[28] 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.
[29] Waghmare P. Bibliometric Analysis of Global Research Trends on E-Waste Management from Scopus Database seen through Biblioshiny. Vol. 2021, Library Philosophy and Practice. 2021. p. 1–16.
[30] Haug J, Fischer D, Hagel G. Development of a Short Form of the Index of Learning Styles for the Use in Adaptive Learning Systems [Internet]. ACM International Conference Proceeding Series. 2023. p. 194–8. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85163505652&doi=10.1145%2f3593663.3593675&partnerID=40&md5=69382340f0839118959afce2b578a8a8