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Personalized Learning and Adaptive Systems in Education: A Comprehensive Bibliometric Analysis

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Abstract. Personalized learning and adaptive learning have emerged as pivotal paradigms in 21st-century education, driven by the integration of artificial intelligence and learner-centered technologies. Despite the rapid growth of scholarly contributions in this domain, a comprehensive synthesis that captures its thematic, temporal, and geographic dynamics has remained lacking. This study aims to map the research landscape of personalized and adaptive learning from 2001 to 2025 through a bibliometric analysis of 922 peer-reviewed documents sourced from the Scopus database. Utilizing bibliometric mapping tools including VOSviewer and Biblioshiny, the study analyzed publication trends, source impact, authorship, international collaboration, keyword co-occurrence, and thematic evolution. The findings reveal a significant surge in publications post-2015, peaking in 2023, indicating an intensifying global focus on individualized educational systems. Key dissemination venues include *Lecture Notes in Computer Science*, *IEEE Access*, and the *ACM International Conference Proceeding Series*. Influential contributors such as Hwang G.-J., Lin F., and Rezai A. were identified, along with a geographic concentration of output in China, the United States, and India. Keyword analysis highlights a transition from early emphases on "learning styles" to recent themes such as "ChatGPT," "reinforcement learning," and "inclusive education." This study offers a longitudinal and multi-dimensional overview of the field, integrating diverse data points into a coherent intellectual narrative. The results serve

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as a strategic reference for scholars, policymakers, and practitioners, informing future research, innovation, and policy direction in the development of intelligent and adaptive learning environments.

Keywords: Personalized learning; adaptive learning; bibliometric analysis; artificial intelligence; learning analytics

1. Introduction

In recent years, personalized learning and adaptive learning have become two of the most prominent paradigms shaping contemporary educational innovation. Their rise is largely attributed to the increasing integration of artificial intelligence (AI) and data-driven systems into pedagogical practices. As education transitions from standardized instruction toward learner-centered models, adaptive technologies such as AI-enabled learning systems provide pathways for tailoring educational experiences to individual learner profiles (Plooy et al., 2024; Hariyanto 2025; Lee et al., 2021). This shift is not only pedagogical but also deeply technological, as reflected in the expanding volume of research dedicated to intelligent learning environments, learning analytics, and machine learning in education (Gligorea et al., 2023; Wang. et al., 2024).

The global academic community has responded with a growing body of research to explore, evaluate, and implement these innovations. Initial interest in the early 2000s was modest, as indicated by fewer than ten publications per year prior to 2008. However, after 2015, the field experienced exponential growth, culminating in a peak of 255 publications in 2023 alone, as documented by recent bibliometric analysis. This dramatic rise in scholarly output underscores both the maturity and complexity of the field. Scholars such as Hwang et al. (2012); Lin et al. (2024); Lin et al. (2022); Xie et al. (2019), have made significant contributions in mapping this evolution across contexts ranging from intelligent tutoring systems to generative AI-based platforms.

Despite the voluminous research, there remains a lack of comprehensive synthesis that maps the thematic, temporal, and geographic dimensions of the field. Earlier studies often focused on specific technologies or educational contexts without capturing the broader intellectual landscape. This fragmentation limits our understanding of how various innovations converge, diverge, or evolve over time. Consequently, stakeholders including policymakers, educators, and developers face challenges in identifying dominant trends, influential contributors, and emerging research directions. Bibliometric mapping offers a robust solution to this challenge.

By systematically analyzing metadata from academic publications, bibliometric analysis can reveal structural patterns, thematic clusters, and intellectual linkages within a research domain. Using tools such as VOSviewer and Biblioshiny, it becomes possible to construct network visualizations and thematic maps that not only depict current research concentrations but also highlight emerging frontiers. This methodological approach has proven effective in various domains, including

science, engineering, and education, as demonstrated by (Bancong, 2024; Nanda et al., 2025).

A closer examination of recent high-impact studies demonstrates how bibliometric tools have facilitated strategic insights in the personalized and adaptive learning domain. Xie et al. (2019) for example, conducted a systematic review of technology-enhanced personalized learning from 2007 to 2017 and identified key publication venues, influential authors, and methodological patterns. Their work set a foundation for subsequent research but was limited in scope to journal publications and a decade-long window. More recent analyses have expanded this scope significantly.

Rezai et al. (2024) examined the role of ChatGPT in supporting L2 development, demonstrating the real-time impact of generative AI on learner engagement and content personalization. Likewise, Troussas et al. (2025) explored contextual schemas to enhance chatbot responses in personalized educational systems. These studies illustrate the field's trajectory toward applied AI technologies, yet they are case-specific and lack an overarching synthesis across time and geography. Studies like those by Le et al. (2024); Lin and Chen (2025); Nguyen et al. (2023) have utilized algorithmic models and contextual bandit frameworks to generate adaptive learning sequences, showing a shift from static instructional design to dynamic, learner-responsive models. However, while their methodologies are sophisticated, they too often remain isolated from broader bibliometric mapping that would allow for meta-level interpretation.

The collective body of literature reviewed reveals four primary research gaps. First, there is a temporal discontinuity, where most reviews do not encompass the full developmental arc from 2001 to 2025. Second, the bibliographic coupling between countries, as shown in recent analyses, remains underexplored in terms of its impact on international collaboration and thematic convergence. Third, thematic evolution, especially the shift from "learning styles" to "generative AI" has not been consistently mapped across periods, leading to a lack of understanding of conceptual transitions. Fourth, while keyword co-occurrence and thematic clustering have been employed in individual studies, a comprehensive synthesis that integrates annual trends, source impact, author prominence, and geographic dispersion remains absent. Without such synthesis, the field lacks a cohesive narrative that links micro-level innovations with macro-level trends. This gap impairs strategic planning for future research and hinders cross-disciplinary integration.

This study aims to conduct a comprehensive bibliometric analysis of research trends in personalized and adaptive learning from 2001 to 2025. The novelty of this study lies in its methodological synthesis and temporal coverage. Unlike previous studies that focus on narrow timeframes or limited scopes, this work provides a longitudinal, multi-dimensional mapping of the field using validated tools such as VOSviewer and Biblioshiny. Moreover, the study contributes a macro-perspective that integrates individual innovations into a coherent narrative of field development. It leverages the strengths of earlier works Aria et al. (2023,

2024); Aria and Cuccurullo (2017) while extending their frameworks to a broader and more contemporary dataset.

The scope of this research is limited to peer-reviewed publications indexed in the Scopus database and written in English. It excludes non-peer-reviewed literature and non-English sources. The dataset includes 922 documents comprising journal articles, conference proceedings, book chapters, and reviews. This scope ensures both comprehensiveness and methodological rigor in capturing the scholarly landscape of personalized and adaptive learning.

The study is guided by six interrelated research questions:
1) How has the volume and source distribution of scholarly output on personalized and adaptive learning evolved over time?
2) Who are the most influential contributors and which countries demonstrating the highest research engagement in this domain?
3) What are the dominant themes, keyword patterns, and conceptual structures shaping the field's development?

2. Methodology

This study employed a bibliometric mapping method to analyze the development and trends in personalized and adaptive learning over a 25-year period (2001–2025). The primary source of bibliographic data was the Scopus database (https://www.scopus.com), one of the most comprehensive and multidisciplinary abstract and citation repositories of peer-reviewed literature. Scopus was selected due to its broad disciplinary coverage, advanced filtering capabilities, and recognized credibility in bibliometric research (Aria & Cuccurullo, 2017; Visser et al., 2021). A systematic search was conducted on July 17, 2025, using the keyword phrase "personalized learning and adaptive learning."

The query was executed through the TITLE-ABS-KEY field to retrieve documents containing the keywords in the title, abstract, or author-defined keywords. The initial search yielded 953 documents. To ensure quality and relevance, inclusion and exclusion criteria were applied in line with standard bibliometric research practices (Donthu et al., 2021; Zupic & Čater, 2015). First, the time frame was limited to 2001–2025. Second, document types were filtered to include journal articles, conference papers, book chapters, and conference reviews, resulting in 933 documents. Third, only English-language publications were retained, narrowing the final dataset to 922 documents, which formed the basis for the bibliometric analysis.

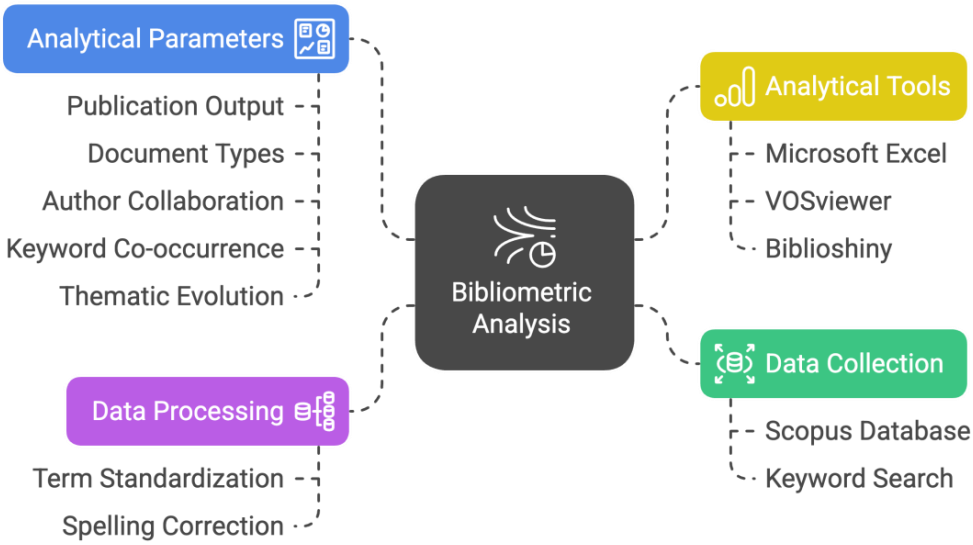

Figure 1: Framework of bibliometric analysis process

Following the selection process, the 922 bibliographic records were exported from the Scopus database in two formats: comma-separated values (CSV) and Research Information Systems (RIS). These formats were compatible with the bibliometric tools used in the study and facilitated both quantitative and qualitative metadata analysis. The exported datasets included essential bibliographic fields such as authorship information, publication year, source title, institutional affiliations, document type, keywords, abstracts, and citation counts. Prior to analysis, data preprocessing was conducted to standardize terms, correct spelling variations, and unify synonymous expressions particularly in the keywords field to avoid analytical redundancy. This step was vital for enhancing the accuracy of keyword co-occurrence and thematic clustering visualizations (Aria and Cuccurullo, 2017).

The bibliometric analysis was conducted using a combination of Microsoft Excel (for initial data tabulation and filtering), VOSviewer, and Biblioshiny, the web-based interface of the bibliometrix R package (Aria et al., 2023; Aria and Cuccurullo, 2017). VOSviewer was applied primarily for network visualization, enabling the construction of co-authorship, keyword co-occurrence, bibliographic coupling, and country collaboration maps (Visser et al., 2021). The software's capacity to cluster and label intellectual structures graphically allows for the identification of research frontiers and thematic evolution.

Biblioshiny, in turn, was used to generate descriptive bibliometric indicators such as annual publication trends, source impact, authorship patterns, and keyword dynamics and to perform strategic diagrams (thematic maps) and factorial analyses (conceptual structure maps). The integration of both tools ensured a comprehensive mapping of the knowledge domain and facilitated robust pattern identification (Aria et al., 2024).

Several analytical parameters were considered in this study, following established bibliometric research practices (Aria & Cuccurullo, 2017; Donthu et al., 2021;

Zupic & Čater, 2015). First, publication output by year was tracked to assess the temporal growth of research interest. Second, document types and source titles were analyzed to identify dominant dissemination channels. Third, author collaboration was explored through co-authorship analysis, revealing prolific contributors and institutional affiliations. Country-level participation was visualized using bibliographic coupling and MCP-SCP (multiple-country publication vs. single-country publication) analysis to evaluate international collaboration patterns. Keyword co-occurrence and co-citation networks were analyzed to identify conceptual linkages and intellectual base structure. Thematic evolution was mapped by dividing the timeline into four distinct periods: 2001–2008, 2009–2016, 2017–2023, and 2024–2025.

This approach highlighted the emergence, transformation, or decline of major research themes over time (Bancong, 2024; Nanda et al., 2025). To generate thematic maps, themes were categorized based on two metrics: centrality (relevance) and density (development level), placing them in quadrants such as motor themes, basic themes, niche themes, and emerging/declining themes. These visual tools provided insights into the structural and dynamic properties of the field.

No inferential statistics were applied due to the descriptive nature of bibliometric analysis. However, quantitative indicators were computed to assess publication impact and collaboration strength. Total citations (TC), average citations per document, h-index values, and link strength (in co-authorship and co-occurrence networks) were calculated using bibliometrix and VOSviewer(Aria and Cuccurullo, 2017; Eck & Waltman, 2017). Normalization techniques within VOSviewer ensured that co-authorship, keyword frequencies, and bibliographic coupling strength were scaled appropriately, preventing bias from highly prolific entities. Network clustering was performed using the default LinLog layout and fractional counting, which ensured accurate depiction of thematic proximities and authorial relationships.

Collectively, this methodological framework offered a robust, replicable, and transparent process for mapping the intellectual landscape of personalized and adaptive learning research. It integrated reliable data sources, established analytical tools, and validated frameworks, as seen in prior bibliometric studies in science and education domains (Aria et al., 2024; Bancong, 2024; Nanda et al., 2025).

3. Result

3.1 Yearly Trend of Publications and Citation

To address the first research question regarding the evolution of scholarly output over time, Figure 2 illustrates the number of publications per year from 2001 to 2025. The trend reveals a significant increase in research interest, particularly after 2017, indicating a growing academic focus on personalized and adaptive learning. This surge may be attributed to advancements in learning analytics and the broader adoption of AI in education systems.

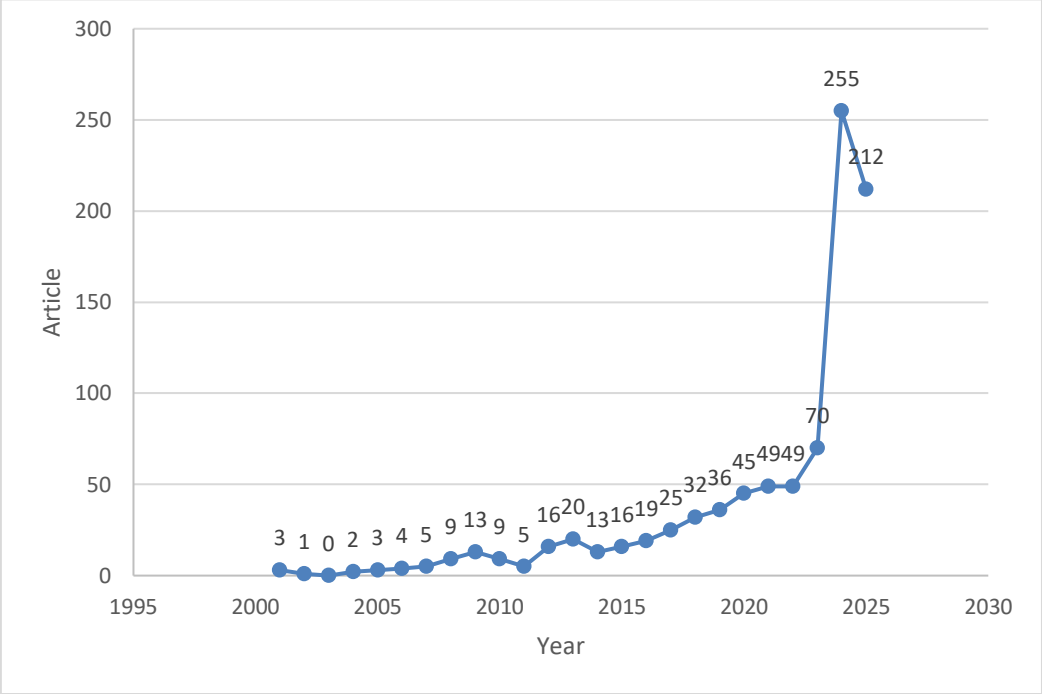

Figure 2: Number of articles published each year from 2001 to 2025

Figure 2 presents the annual distribution of publications on personalized learning and adaptive learning from 2001 to 2025, based on data extracted from the Scopus database. A total of 922 documents were analyzed, including journal articles, conference papers, book chapters, and conference reviews. The data show that research activity in this domain remained minimal in the early 2000s, with fewer than 10 publications per year between 2001 and 2007.

A steady but moderate increase began around 2008, with a more noticeable rise after 2015. From 2015 to 2021, the publication rate consistently grew from 16 to 49 articles annually. A significant surge occurred in 2023, where the number of publications reached 255 articles, marking the peak over the 25-year span. Although a slight decline followed in 2024, with 212 documents published, the trend remains significantly higher than in all previous years. This sharp increase in the last three years reflects an intensifying interest and research focus in the field of personalized and adaptive learning.

Table 1: Highly cited personalized learning and adaptive learning research

Rank	Title	Year	Source Title	Cited By	Authors
1	Intelligent Music Education System: Utilizing Algorithms for Personalized Learning Experience	2025	International Journal of High Speed Electronics and Systems	1	(Lin and Chen, 2025)
2	Ai-Driven Personalized Learning: Revolutionizing Language Education	2024	2nd Ieee International Conference on Iot, Communication and Automation Technology, Icicat 2024	0	(Istanti et al., 2024)
3	How Can Chatgpt Open Promising Avenues for L2 Development? A Phenomenological Study Involving Efl University Students in Iran	2024	Computers In Human Behavior Reports	25	(Rezai et al., 2024)
4	Quizmaster: An Adaptive Formative Assessment System	2024	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	1	(Lin et al., 2024)
5	Educational Knowledge Graph Creation and Augmentation Via Llms	2024	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	2	(Jhajj et al., 2024)
6	Generating Learning Sequences Using Contextual Bandit Algorithms	2024	Lecture Notes in Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics)	1	(Nguyen et al., 2024)
7	Ai-Powered Language Learning: Enhancing Literacy InThe Digital Age	2024	2024 4th International Conference On Advancement in Electronics And Communication	0	(Saddhono, Suhita, Istanti, et al., 2024)

Rank	Title	Year	Source Title	Cited By	Authors
			Engineering, Aece 2024		
8	Teaching Literature With Ai: Enhancing Education Through Automated Analysis And Interpretation	2024	2nd Ieee International Conference OnIot, Communication And Automation Technology, Icicat 2024	0	(Saddhono, Judijanto, et al., 2024)
9	Innovations In Education: A Deep Dive IntoThe Application Of Artificial Intelligence In Higher Learning	2024	2024 4th International Conference On Advance Computing And Innovative Technologies In Engineering, Icacite 2024	1	(Nugraheni et al., 2024)
10	A Design Of Virtual Classrooms Through Ai, MlAnd Dl To Improve The Level Of Learning	2024	2024 4th International Conference On Advance Computing And Innovative Technologies InEngineering, Icacite 2024	1	(Nurhasanah et al., 2024)
11	Ai And Literacy: Developing Critical Thinking And Analytical Skills InThe Digital Era	2024	2nd Ieee International Conference OnIot, Communication And Automation Technology, Icicat 2024	0	(Saddhono, Suhita, Rakhmawati, et al., 2024)
12	Enhancing Educational Outcomes Through Exploring The Optimized Options Artificial Intelligence And Deep Learning	2024	2024 4th International Conference On Advance Computing And Innovative Technologies In Engineering, Icacite 2024	2	(Legowo et al., 2024)
13	Adaptive Sequence Learning: Contextual Multi-Armed Bandit Approach	2023	2023 Ieee International Conference On Dependable, Autonomic And Secure Computing, International Conference On	1	(Nguyen et al., 2023)

Rank	Title	Year	Source Title	Cited By	Authors
			Pervasive Intelligence And Computing, International Conference On Cloud And Big Data Computing, International Conference On Cyber Science And Technology Congress, Dasc/Picom/Cbdcom/Cyberscitech 2023		
14	Adaptive Technologies And Augmented Realities: A Section Introduction	2023	Learning, Design, And Technology: An International Compendium Of Theory, Research, Practice, And Policy	0	(Hwang and Chen, 2023)
15	Learning Optimal And Personalized Knowledge Component Sequencing Policies	2022	Lecture Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics)	1	(Lin et al., 2022)
16	Multi-Armed Bandit Algorithms For Adaptive Learning: A Survey	2021	Lecture Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics)	10	(Mui et al., 2021)
17	Trends And Development In Technology-Enhanced Adaptive/Personalized Learning: A Systematic Review Of Journal Publications From 2007 To 2017	2019	Computers And Education	443	(Xie et al., 2019)
18	Hipatia: A Hypermedia Learning Environment In	2016	Anales De PsicologiaEducational Technology And Society	14	(Cueli et al., 2016)

Rank	Title	Year	Source Title	Cited By	Authors
	Mathematics; [Hipatia: Un Entorno De AprendizajeHipermedia En Matemáticas] An Object-Oriented Course Framework For Developing Adaptive Learning Systems				
19	A Multi-Dimensional Personalization Approach To Developing Adaptive Learning Systems	2013	Lecture Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics)	6	(Yang et al., 2013)
20	Development Of A Personalized Educational Computer Game Based On Students' Learning Styles	2012	Educational Technology Research And Development	229	(Hwang et al., 2012)
21	A Learning Style Perspective To Investigate Students' Perceptions In Choosing The Most-Beneficial Educational Systems	2011	Proceedings Of The 19th International Conference On Computers In Education, Icce 2011	0	(Sung et al., 2011)
22	Developing A Knowledge Graph For Intelligent Structural Design Course	2025	Proceedings Of 2024 3rd International Conference On Artificial Intelligence AndEducation, Icaie 2024	0	(Zhao et al., 2025)
23	Fuzzy Memory Networks And Contextual Schemas: Enhancing Chatgpt Responses InA Personalized Educational System	2025	Computers	0	(Troussas et al., 2025)
24	A Duplex Adaptation Mechanism InThe Personalized Learning Environment	2024	Journal Of Computers In Education	1	(Wongwatkit and Panjaburee, 2024)

Rank	Title	Year	Source Title	Cited By	Authors
25	Personalized Learning Via Gamified Virtual Environments: Exploring Insights And Impact	2024	Proceedings - 2024 19th International Workshop On Semantic And Social Media Adaptation And Personalization, Smap 2024	0	(Strousopoulos and Troussas, 2024)

The trend in highly cited publications within personalized and adaptive learning indicates a diversification of research interests and a progressive integration of artificial intelligence (AI) technologies. One of the most impactful studies, with 443 citations, is the systematic review by Xie et al. (2019), which comprehensively assessed developments from 2007 to 2017, emphasizing journal publications and laying foundational insights into the field's evolution. Similarly, the study by Hwang et al. (2012), cited 229 times, explored the role of learning styles in personalizing educational computer games, underscoring the pedagogical shift toward learner-centered approaches.

More recent works in 2024 and 2025 reflect the field's rapid evolution toward the application of large language models and AI algorithms. For instance, Rezai et al. (2024) investigated the role of ChatGPT in supporting L2 language development, achieving 25 citations within a short span indicating immediate academic impact and practical relevance. Other studies such as those by (Lin and Chen, 2025; Troussas et al., 2025) represent the integration of algorithmic and memory network-based solutions for personalized learning environments, though these remain less cited, suggesting either novelty or limited dissemination.

Compared to earlier works focused on conceptual frameworks or learner styles, the recent literature reveals a shift toward empirical implementation of adaptive technologies, such as context-aware systems (Nguyen et al., 2024) and educational knowledge graphs (Jhajj et al., 2024). While the volume of research has increased, the citation disparity highlights the time-lag effect in impact metrics and the need for continuous validation and longitudinal studies to determine enduring relevance. The current review contributes by consolidating diverse research trajectories and mapping their progression over time.

Unlike earlier reviews that focused narrowly on adaptive learning in specific contexts (e.g., higher education) or provided only cross-sectional snapshots of the literature (Plooy et al., 2024; Guo et al., 2024; Jing et al., 2023), this study offers an integrative and longitudinal perspective spanning 2001–2025. In doing so, it bridges conceptual foundations and empirical developments, presenting a holistic understanding of how personalized and adaptive learning research has evolved globally.

3.2 Most Relevant Sources

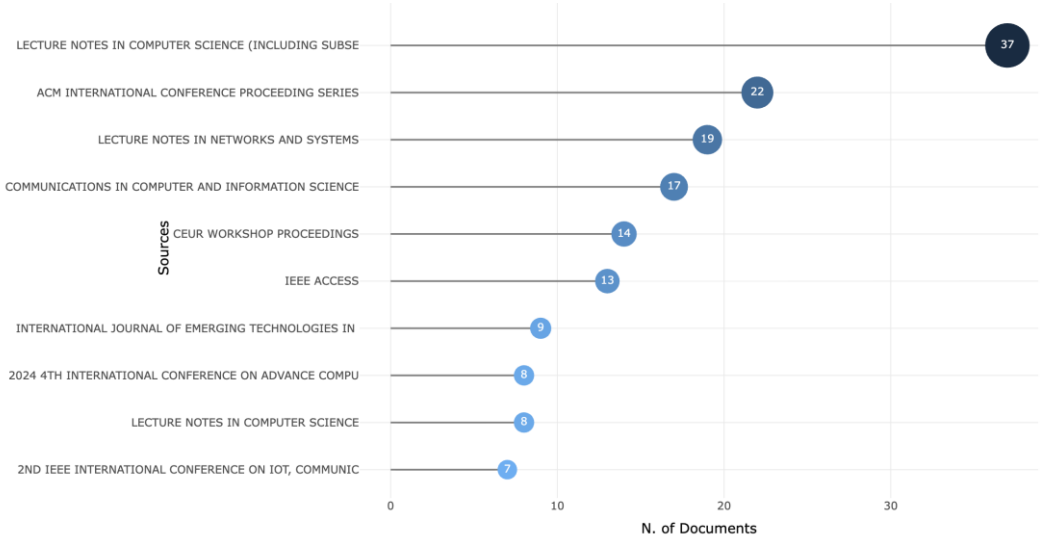

Figure 3: Source-wise distribution of publications on personalized and adaptive learning (2001–2025)

Figure 3 presents the distribution of the most prolific publication sources in the field of personalized and adaptive learning, based on the number of documents published between 2001 and 2025. The *Lecture Notes in Computer Science* (including its AI and bioinformatics subseries) stand out as the most dominant venue, contributing 37 publications, which reflects the strong technical foundation of research in this domain. This is followed by the *ACM International Conference Proceeding Series* (22 documents), and *Lecture Notes in Networks and Systems* (19 documents), both of which further emphasize the computing and engineering-centric nature of the field. Other notable sources include *Communications in Computer and Information Science* (17 documents), *CEUR Workshop Proceedings* (14), and *IEEE Access* (13), each playing a key role in disseminating interdisciplinary work that merges educational theory with advanced computing technologies.

The presence of more recent conferences, such as the *2024 4th International Conference on Advance Computing* and the *2nd IEEE International Conference on IoT, Communication and Automation Technology*, indicates the increasing momentum and visibility of personalized learning research in emerging technology venues. Collectively, these source titles demonstrate that personalized and adaptive learning is a rapidly growing field anchored in computer science but expanding toward more diverse, interdisciplinary platforms. Visual representation in Figure 3 aids in identifying high-impact venues for researchers and practitioners seeking publication or literature in this evolving domain.

Table 2: Most source titles that contribute to the publication on personalized learning and adaptive learning

Rank	Relevant Source	Document	Citation	Total Link Strength
1	Acm international conference proceeding series	22	103	3
2	Lecture notes in networks and systems	20	20	3
3	Communication in computer and information science	17	66	2
4	Ceur workshop proceedings	14	47	1
5	Ieee access	14	250	3
6	Educational technology and society	6	221	6
7	Interactive learning environments	7	432	6
8	Smart learning environments	5	746	6
9	Applied sciences (Switzerland)	7	240	4
10	British journal of educational technology	5	184	2

Table 2 presents the ten most influential source titles contributing to the body of research on personalized and adaptive learning. The *ACM International Conference Proceeding Series* ranks first with 22 documents, accumulating 103 citations and a total link strength of 3. This is followed by *Lecture Notes in Networks and Systems*, which contributed 20 documents, although with a relatively lower citation count of 20.

Notably, *IEEE Access* and *Applied Sciences (Switzerland)*, despite publishing fewer documents (14 and 7 respectively), show a high citation impact with 250 and 240 citations correspondingly. *Interactive Learning Environments* and *Smart Learning Environments* demonstrate substantial academic influence with 432 and 746 citations respectively, though with fewer contributions (7 and 5 documents), indicating a higher average citation rate per article. Similarly, *Educational Technology and Society* and the *British Journal of Educational Technology* show significant citation metrics (221 and 184 citations) with modest publication counts, reinforcing their reputational strength in the educational technology domain.

3.3 Most Influential Authors

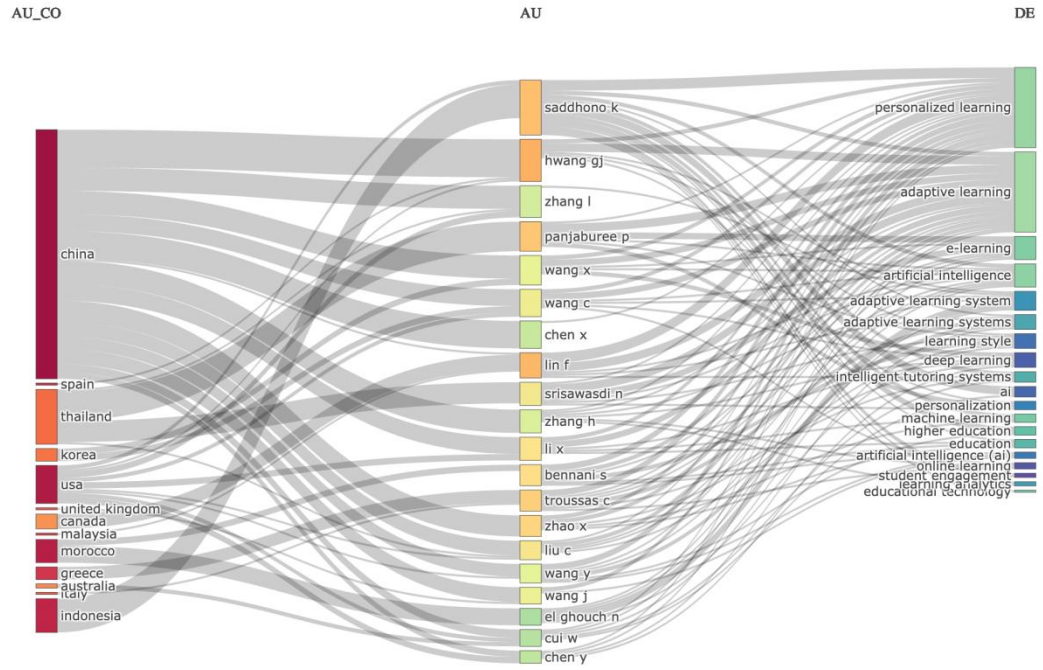

Figure 4: Three field plot connecting countries, authors, and keywords in personalized and adaptive learning research (2001–2025)

Figure 4 illustrates a three-field plot connecting countries of origin, authors, and their dominant research keywords in the domain of personalized and adaptive learning. This visualization underscores several critical insights. First, China leads as the most prolific country, linking to numerous active authors such as Wang X, Chen X, and Lin F, who contribute substantially to research themes like "adaptive learning," "e-learning," and "artificial intelligence." Thailand, Indonesia, and Spain also show prominent involvement, with figures such as Hwang GJ, Saddhono K, and Panjaburee P indicating diversified global engagement.

Thematically, the keywords associated with these authors reflect the evolving conceptual landscape of the field. While foundational themes like "personalized learning" and "learning style" remain central, there is an evident expansion toward sophisticated technological concepts including "deep learning," "intelligent tutoring systems," and "educational technology." This reflects a broader shift from theoretical models to applied, AI-driven frameworks that support learning personalization.

These findings highlight the interdisciplinary and international nature of the research community. Scientifically, they confirm that personalized and adaptive learning is a mature and expanding research domain with contributions emerging from both technologically advanced and developing regions. Practically, they emphasize the importance of fostering cross-border academic collaborations to enhance innovation, context relevance, and scalable solutions. The integration of authorial productivity, geographic diversity, and evolving thematic foci provides stakeholders policymakers, educators, and developers with a strategic map for

engaging with leading voices and emerging trends in the field. While prior reviews such as Guo et al. (2024); Jing et al. (2023) examined individual dimensions like author impact or geographic output, they did not offer a multi-dimensional synthesis that interlinks these aspects. In contrast, this study bridges these fragmented angles into a cohesive framework that informs both academic inquiry and practical engagement.

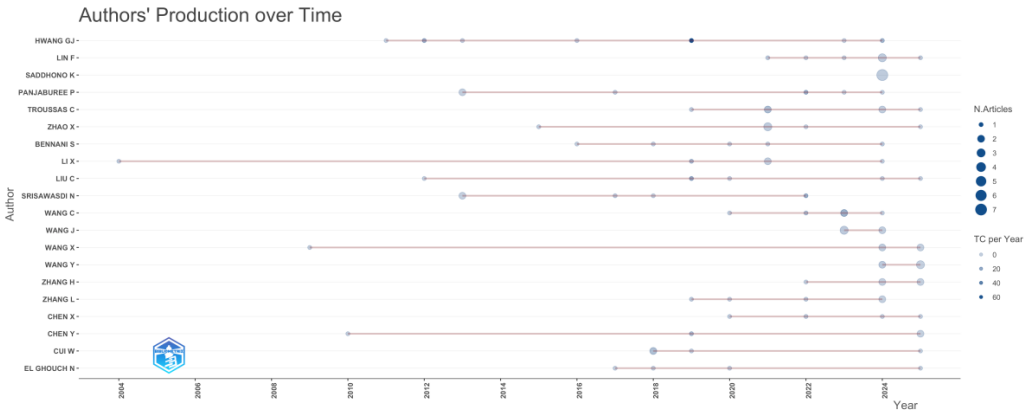

Figure 5: Authors' scholarly production over time

Figure 5 reinforces and deepens the insights derived from earlier figures by visualizing both the productivity (number of articles) and citation impact (TC per year) of leading scholars over time. Hwang GJ and Lin F emerge as dominant figures, with consistent output since the mid-2000s and sustained citation influence particularly in the period from 2018 onward. This corresponds with their recognized contributions to adaptive learning frameworks and intelligent learning environments in previous reviews (Hwang et al., 2012; Xie et al., 2019).

In contrast, authors like Saddhono K and Troussas C, while more recent in their contributions, exhibit significant influence in the most current years, reflecting their alignment with contemporary research frontiers such as AI-driven personalization and ChatGPT-based systems (Rezai et al., 2024; Saddhono et al., 2024). Panjaburee P and Bennani S also demonstrate steady outputs that span at least a decade, indicating both sustained engagement and emerging recognition in the scholarly community.

Compared with earlier literature that con the advantage of this study lies in its ability to situate both established and emerging researchers within the evolving landscape of personalized learning, enabling a holistic understanding of scholarly momentum and guiding future collaborations. Previous bibliometric reviews Guo et al. (2024); Jing et al. (2023) typically focused on identifying top authors based on publication count or citation impact. However, they did not explore how these contributors intersect with emerging thematic developments or shift over time. In contrast, this study integrates author-level analysis with longitudinal topic mapping, offering a more dynamic and actionable representation of the field's intellectual structure.centrated on a smaller pool of long-standing contributors, the current data reveal a diversification in both the author base and thematic

scope. This shift underscores the field's growing inclusivity and the relevance of newer voices.

3.4 Most Influential Country

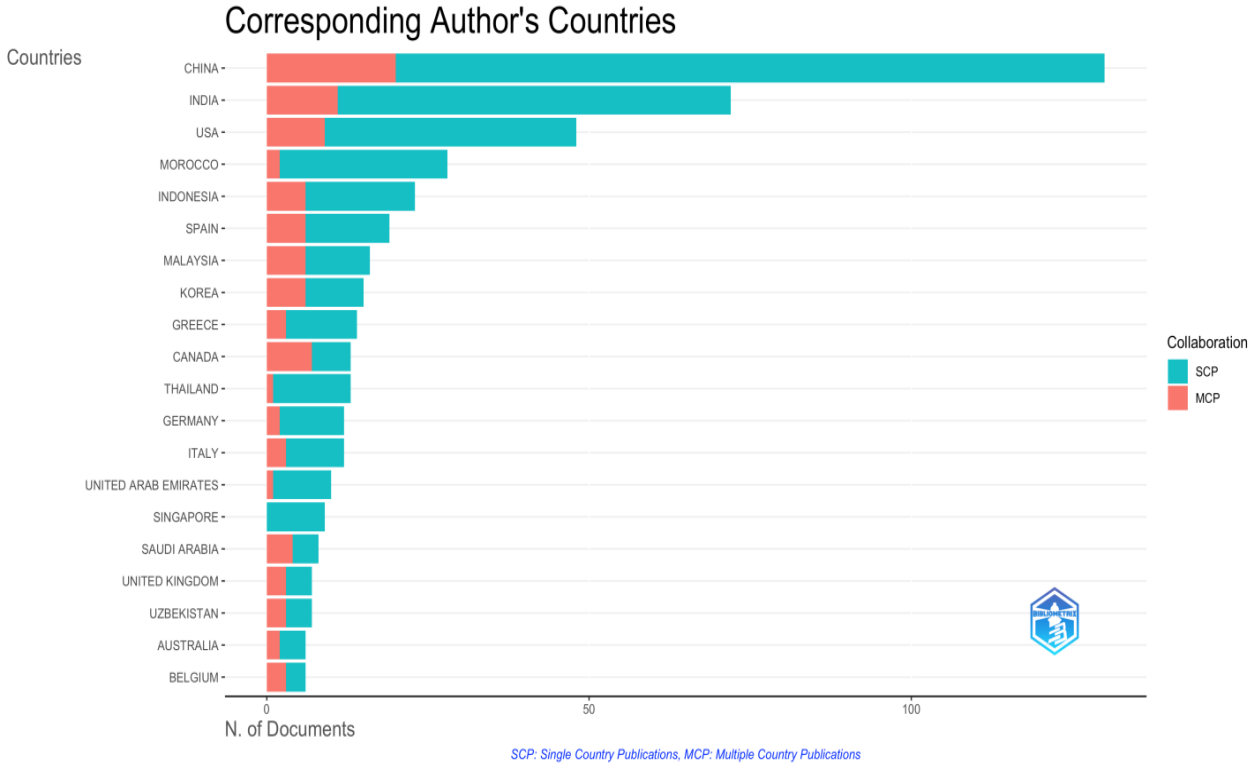

Figure 6: Corresponding author's counties: geographical collaboration: single-country and multiple-country publications

Figure 6 highlights the geographical distribution of corresponding authors by country, distinguishing between single-country publications (SCP) and multiple-country publications (MCP). China emerges as the dominant contributor, with the highest number of documents authored domestically, indicating a strong national research base in personalized and adaptive learning. India and the United States follow closely, with notable levels of both independent and collaborative publications. Countries such as Morocco, Indonesia, and Spain also demonstrate active participation, albeit at lower volumes. The balance between SCP and MCP reveals critical insights into international collaboration. While China and India exhibit a strong emphasis on domestic research, countries like Morocco, Malaysia, and Canada show a relatively higher proportion of international collaborations, as indicated by the MCP bars.

Previous bibliometric studies have reported global participation patterns (Guo et al., 2024; Y. Jing et al., 2023a), but often lacked a comparative view of collaboration strategies among emerging and established research hubs. In contrast, this study not only quantifies geographic output but distinguishes between single- and multiple-country publications, offering a nuanced view of national versus international research behaviors that reflect structural priorities and engagement models across regions. This suggests varying strategies in knowledge production,

some emphasizing national capacity-building, others integrating into global research networks.

The findings underscore global dispersion and strategic collaboration in the field. Scientifically, it affirms that personalized learning is a widely relevant topic transcending regional boundary. Practically, it signals the importance of fostering cross-border research partnerships to leverage localized innovations and address diverse educational challenges. For policymakers and funding agencies, the visualization provides evidence of active regions and potential hubs for international academic exchange, thereby informing future investment and collaboration strategies.

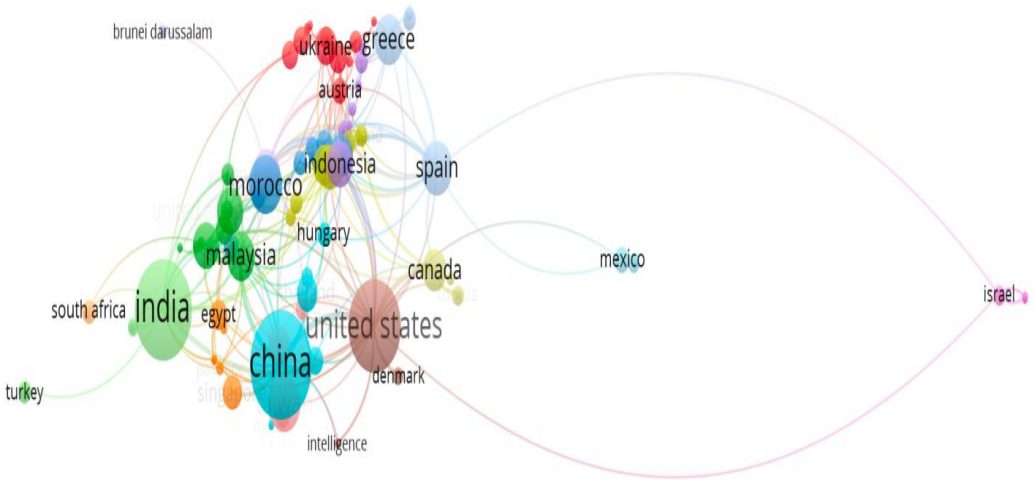

Figure 7: Bibliographic coupling of countries

Figure 7 displays the bibliographic coupling of countries, illustrating the extent of intellectual connectivity and shared citation patterns among nations contributing to personalized and adaptive learning research. The visualization reveals several prominent clusters. China, the United States, and India are situated at the core, represented by large nodes and dense interlinkages, indicating both high publication volume and extensive citation interrelationships with other countries.

Other active nodes include Malaysia, Morocco, Indonesia, and Spain, which show substantial bibliographic connections, highlighting their integration into regional and international citation networks. Notably, countries such as Greece, Ukraine, Austria, and Hungary are positioned within medium-sized clusters, reflecting moderate connectivity. Meanwhile, Israel appears isolated with minimal linkage, signifying limited bibliographic coupling with the broader network. Clustering of countries based on citation behavior suggests strong regional collaborations and thematic convergence.

The spatial proximity and linking strength between countries provide insights into shared research interests, institutional collaborations, and co-citation practices that shape the global research landscape in this field. While previous

bibliometric studies Durak et al., (2024); Jing et al. (2023); Koutsantonis et al. (2022), have mapped national publication output and thematic trends, they typically stopped short of analyzing the intellectual connectivity between countries. In contrast, this study employs bibliographic coupling to reveal how nations are interlinked through shared citation patterns highlighting deeper scholarly relationships that transcend mere publication counts. This approach offers a more nuanced understanding of regional and global knowledge that flows in personalized and adaptive learning research.

3.5 Most Relevant Keywords

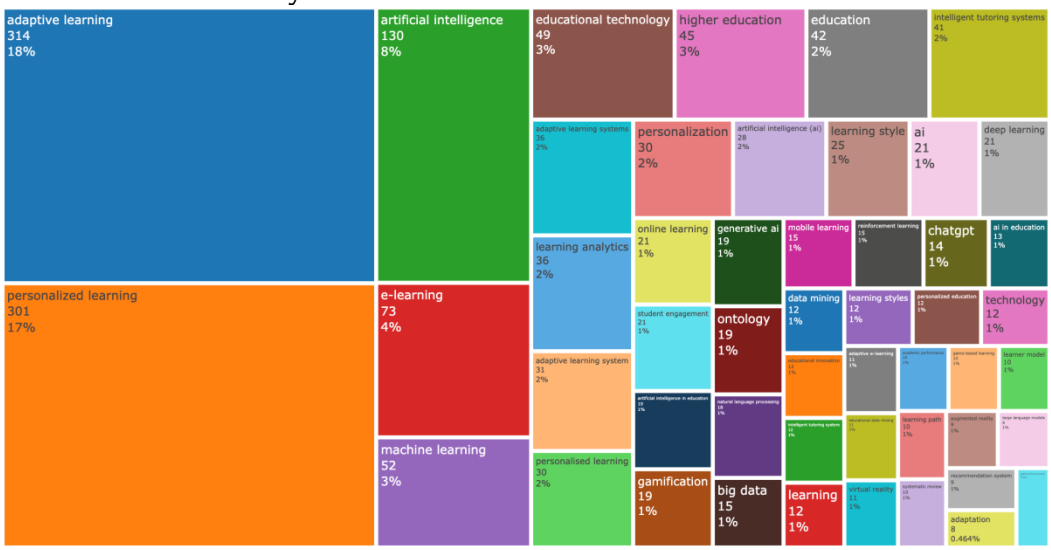

Figure 8: Tree map of authors' keywords

Figure 8 presents a tree map of authors' keywords, revealing the thematic composition and co-occurrence frequency within the domain of personalized and adaptive learning. Dominant keywords such as *"adaptive learning"* (314 occurrences) and *"personalized learning"* (301 occurrences) underscore the central pillars of the field. Their comparable frequencies reaffirm their conceptual interdependence, as observed in high-citation studies like (Hwang et al., 2012; Xie et al., 2019)., which laid early theoretical foundations. Closely associated terms such as *"artificial intelligence"* (130), *"e-learning"* (73), *"machine learning"* (52), and *"learning analytics"* (36) reflect a shift toward AI-augmented education systems.

This aligns with recent advancements introduced by (Rezai et al., 2024) who developed AI-powered adaptive frameworks and generative AI-supported platforms. The emergence of keywords like *"ChatGPT"*, *"generative AI"*, *"ontology"*, and *"big data"* signals the field's expansion into novel domains of human-computer interaction and data-driven pedagogy. In contrast to earlier bibliometric reviews that predominantly highlighted static concepts like *"learning styles"* or *"intelligent tutoring systems"* (Koutsantonis et al., 2022), the presence of terms such as *"reinforcement learning"*, *"recommendation system"*, and *"gamification"* reflects a broader conceptual evolution and diversification.

This study offers a richer portrayal by bridging foundational constructs with contemporary trends, thereby enabling stakeholders to trace how core ideas have

transformed and diversified over time. Consequently, the present analysis not only updates but expands the existing knowledge base. It provides holistic and future-facing thematic mapping going beyond the scope of previous reviews to inform ongoing research directions and pedagogical innovation

3.6 The Current Research Landscape

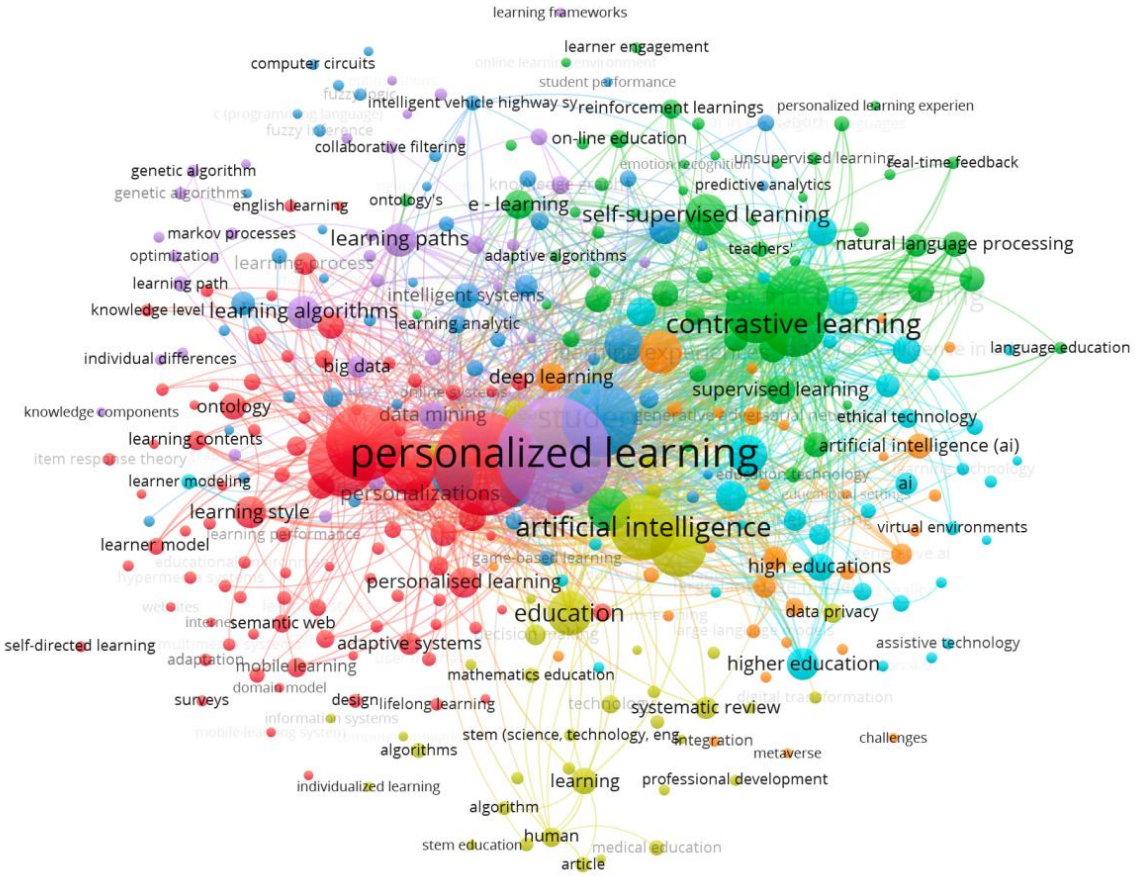

Figure 9: Keywords co-occurrence analysis by network visualization

Figure 9 depicts a co-occurrence network of authors' keywords, revealing the intellectual structure and thematic interconnectivity within the domain of personalized and adaptive learning. At the center of the network, *"personalized learning"* and *"artificial intelligence"* function as core nodes, reflecting their conceptual centrality in the discourse. These nodes are tightly connected to themes like *"learning algorithms"*, *"learning paths"*, *"deep learning"*, and *"adaptive systems"*, forming a dense cluster that emphasizes the technological underpinnings of the field. Other key sub-networks such as *"self-supervised learning"*, *"contrastive learning"*, and *"natural language processing"* reflect recent advancements in AI and their increasing role in educational contexts. This is consistent with the emergence of terms like *"ChatGPT"* and *"generative AI"* in the previous tree map (Figure 7), marking the domain's shift toward large language models and machine-generated personalization.

In parallel, enduring pedagogical themes such as *"learning style"*, *"learner engagement"*, and *"lifelong learning"* remain embedded in the network demonstrating that pedagogical and technological dimensions are increasingly interwoven. The significance of this visualization lies in showing how foundational concepts and emerging innovations converge into a unified and maturing scientific community**.** While earlier bibliometric studies Durak, 2024; B. Jing et al., 2024) identified major keywords and tracked topic frequency, they often treated educational and AI themes as independent or parallel strands. In contrast, this study reveals their structural integration, as traditional constructs like *"learning style"* now appear alongside novel AI-driven keywords signifying not just coexistence, but thematic interdependence. This integrated intellectual structure affirms the field's interdisciplinary cohesion and forward momentum. It also validates the thematic evolution captured in RD4.2 and reinforces the connectivity observed in authorship and citation layers (RD2.2, RD3.2). For educators, developers, and policymakers, these insights offer a strategic lens for aligning innovation with pedagogical relevance, guiding future curriculum design, system development, and cross-sector collaboration.

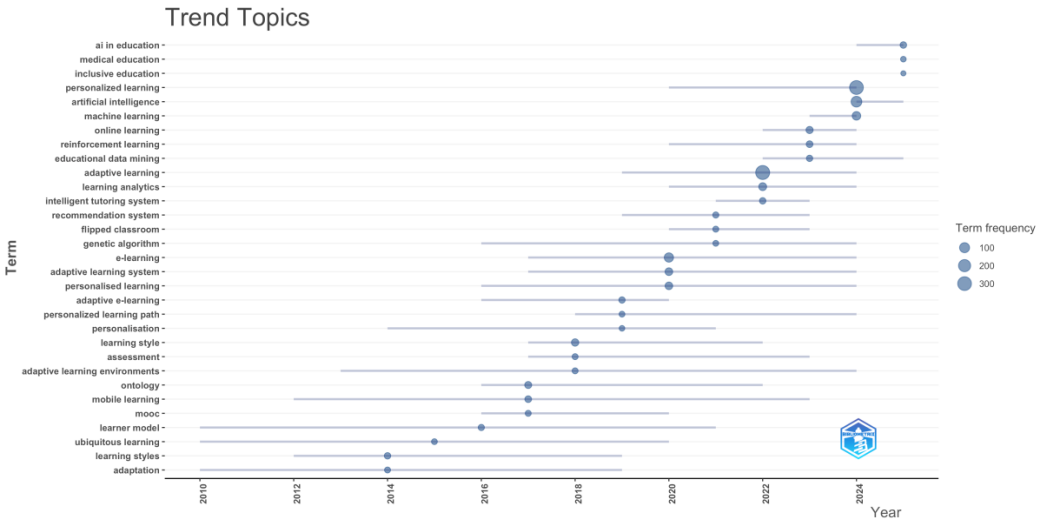

Figure 10: Trend topics of personalized learning and adaptive learning

Figure 10 illustrates the temporal emergence and frequency of trend topics in personalized and adaptive learning research from 2010 to 2024. The visualization reveals a shift from early-stage topics such as "learning styles," "learner model," and "ubiquitous learning" toward more advanced and data-driven terms in recent years. By 2016, the field began emphasizing "e-learning," "ontology," and "mobile learning," reflecting an expansion in technological modalities and learning environments. A significant increase in term frequency is observed from 2020 onward, with high-impact keywords such as "adaptive learning," "machine learning," "artificial intelligence," and "personalized learning" dominating the landscape.

Notably, recent years (2022–2024) mark the rise of more sophisticated and contemporary themes including "reinforcement learning," "AI in education," "inclusive education," and "medical education." These suggest a diversification

in application domains and methodological approaches. The size and persistence of bubbles for "artificial intelligence" and "personalized learning" highlight their sustained prominence and growing relevance. The trend also shows an increasing adoption of predictive, algorithmic, and analytics-based learning systems underscoring a paradigm shift toward intelligent, adaptive, and context-aware educational technologies.

Compared to previous bibliometric reviews Durak et al. (2024); Jing et al. (2023) which primarily cataloged frequent terms without addressing their temporal emergence or lifecycle, this study offers a more dynamic perspective by capturing how core concepts have evolved, expanded, and been replaced over time. The temporal visualization helps identify not just what has been studied, but *when* key transitions occurred providing a strategic tool for anticipating future directions in the field.

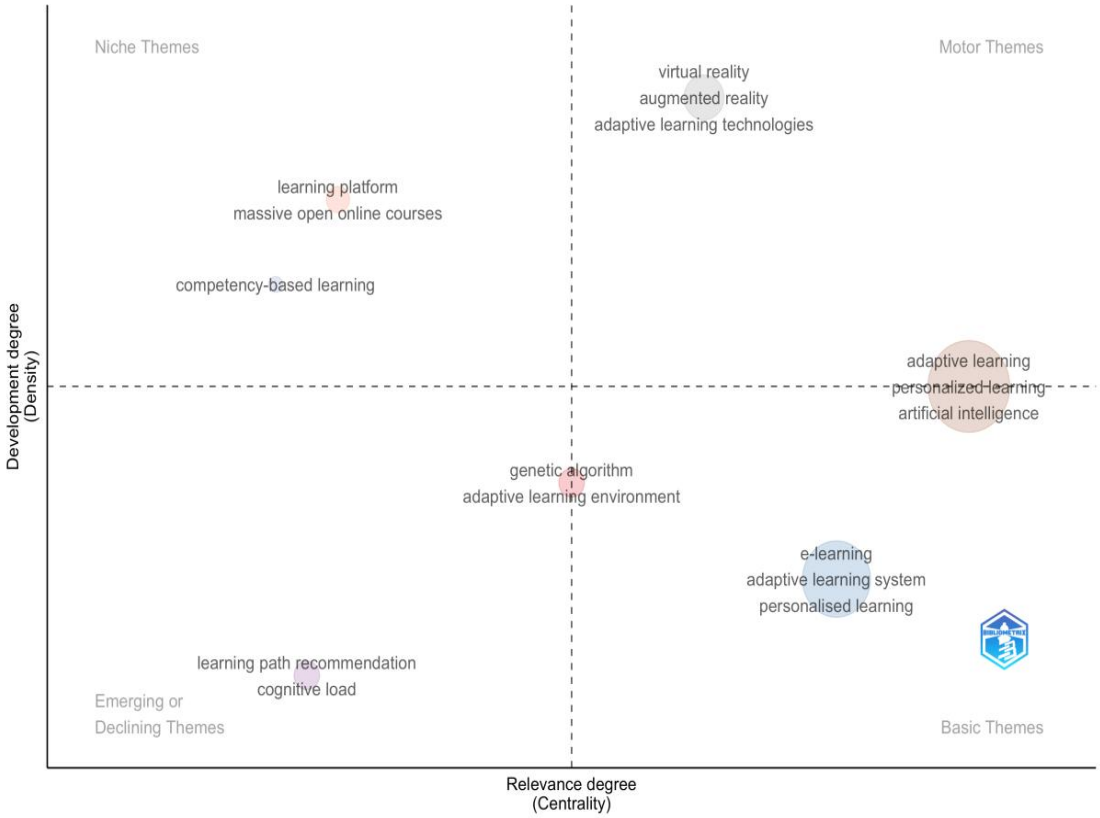

Figure 11: Thematic map of personalized learning and adaptive learning

Figure 11 presents the thematic map of personalized and adaptive learning based on density and centrality, categorizing the topics into four quadrants: motor themes, basic themes, niche themes, and emerging/declining themes. "Adaptive learning," "personalized learning," and "artificial intelligence" are positioned in the upper-right quadrant, indicating their status as well-developed and central motor themes. These are dominant driving forces within the field and are frequently interlinked with technological, pedagogical, and algorithmic advancements, consistent with recent influential works (Lin et al., 2024; Rezai et al., 2024).

In contrast, the lower-right quadrant identifies "e-learning," "adaptive learning system," and "personalized learning" as basic themes. These are essential to the research field, but still under structural development suggesting areas that are foundational yet potentially underexplored in depth. Niche themes such as "learning platform," "MOOC," and "competency-based learning" appear in the upper-left quadrant, reflecting specialized but less integrated lines of inquiry. Their high density but lower centrality implies limited interdisciplinary influence or cross-thematic integration. The lower-left quadrant contains themes like "cognitive load" and "learning path recommendation," categorized as either emerging or declining. Despite their current low development and relevance, they may become future focal points as learning personalization requires more sophisticated models of learner cognition and guidance optimization. Compared to earlier literature which emphasized static or linear theme growth, the current thematic analysis captures the dynamic trajectory of conceptual development.

This review offers a comprehensive snapshot that not only identifies the current research anchors but also highlights underdeveloped domains that warrant further exploration, making it a strategic tool for researchers planning future work. Compared to prior thematic analyses, which often presented linear or taxonomic groupings (Durak et al., 2024; Jing et al., 2023) this study offers a spatial and structural mapping of topic evolution. By plotting density and centrality simultaneously, it captures both conceptual importance and developmental maturity providing a more strategic perspective for scholars navigating research gaps. Similar to findings reported by Wang. et al. (2024) and Hariyanto (2025), this analysis reaffirms the dual trajectories of pedagogical integration and AI-driven innovation shaping the thematic structure of the field.

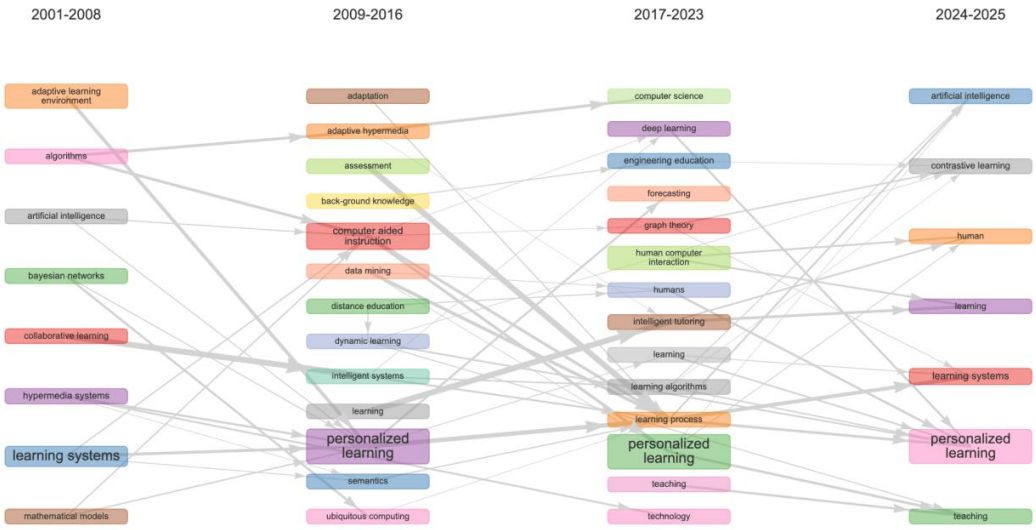

Figure 12: Thematic keyword evolution

Figure 12 illustrates the evolution of thematic keywords in personalized and adaptive learning across four distinct time periods: 2001–2008, 2009–2016, 2017–2023, and 2024–2025. The trajectory clearly shows a conceptual progression from foundational technologies to contemporary, AI-integrated pedagogical models.

During 2001–2008, the discourse was rooted in terms such as "learning systems," "collaborative learning," and "Bayesian networks," reflecting early computational frameworks and theoretical models. Between 2009 and 2016, the emphasis shifted toward "personalized learning," "data mining," and "adaptive hypermedia," marking the beginning of individualized education supported by data-driven systems a transition also noted by (Durak et al., 2024), though their focus was limited to static co-word frequency rather than chronological theme emergence. The period from 2017 to 2023 witnessed the rapid emergence of technologies like "deep learning," "human-computer interaction," and "intelligent tutoring," indicating growing integration of machine intelligence and educational engineering. Finally, in 2024–2025, dominant themes such as "artificial intelligence," "contrastive learning," and the renewed prominence of "personalized learning" reflect the field's maturation and refinement, especially through large-scale AI applications. This thematic evolution aligns closely with the findings presented in Figures 9 and 10, illustrating how basic concepts like "learning systems" have transformed into sophisticated ecosystems leveraging AI for instruction, feedback, and adaptation. An analytical layer that expands beyond earlier work such as (Jing et al., 2023), who primarily clustered terms without tracking their temporal shift.

Scientifically, it captures a longitudinal map of the field's cognitive structure. Practically, it provides educators, system developers, and policymakers with a temporal framework to understand innovation timelines and anticipate future directions in personalized and adaptive learning. Scientifically, it captures a longitudinal map of the field's cognitive structure. Practically, it provides educators, system developers, and policymakers with a temporal framework to understand innovative timelines and anticipate future directions in personalized and adaptive learning.

Figure 13: Keyword frequency representation in personalized and adaptive learning research (word cloud visualization)

Figure 13 presents a word cloud visualizing the frequency and prominence of keywords associated with personalized and adaptive learning research. The

largest terms "personalized learning," "adaptive learning," and "learning systems" indicate their centrality and continued dominance in scholarly discourse. Their presence confirms the thematic consistency observed in Figures 7 through 11, underscoring their role as core constructs in the field.

Other significant terms such as "students," "e-learning," "teaching," and "artificial intelligence" reflect the practical implementation focus of many studies. The inclusion of advanced methodologies such as "federated learning," "adversarial machine learning," "contrastive learning," and "self-supervised learning" demonstrates the integration of frontier AI techniques into educational contexts, confirming the trend observed in recent literature(Lin et al., 2024; Rezai et al., 2024). This visualization reinforces the field's interdisciplinary nature bridging education, artificial intelligence, and human-centered computing. A characteristic that was noted in earlier reviews (Wang. et al., 2024), but less explicitly connected to keyword frequency patterns. Scientifically, it encapsulates the conceptual scope of the research landscape, while practically, it provides stakeholders with a distilled view of key themes guiding innovation and pedagogical transformation.

The prominence of AI-related keywords alongside traditional education terms highlights the fusion of emerging technologies with learner-centric paradigms, offering pathways for scalable and intelligent learning ecosystems. This integrative trajectory builds on prior findings (Hariyanto R., 2025), but offers a more granular reflection of how pedagogical and computational themes now co-evolve in a shared conceptual space.

4. Discussion

The findings confirm a significant evolution in the research landscape between 2001 and 2025. Publication output surged notably after 2015, peaking in 2023, indicating a paradigm shift toward intelligent, individualized, and technology-integrated education. This aligns with (Xie et al., 2019), who documented rapid growth in technology-enhanced personalized learning from 2007–2017. Our analysis extends their findings, capturing the continuing expansion of interest through 2025, particularly in areas like adaptive systems, machine learning, and generative AI. The rise of tools like ChatGPT (Rezai et al., 2024) exemplifies this shift transforming AI from passive support into active facilitators of learning.

As shown in Figures 1–3, computer science and engineering venues such as *Lecture Notes in Computer Science*, *IEEE Access*, and *ACM ICPS* dominate publication sources, reaffirming the computational grounding of the field. This trend aligns with (Visser et al., 2021), who emphasized Scopus' indexing strength in interdisciplinary literature. The high citation performance of landmark works (Hwang et al., 2012; Xie et al., 2019) continues to inform conceptual and methodological innovation, with recent works (Lin et al., 2024; Nguyen et al., 2024) demonstrating operationalization through algorithmic and model-based implementations.

Authorship and collaboration analysis (Figures 4–6) highlight geographic clustering and citation interconnectivity. China, the United States, and India lead

publication volume, while countries like Indonesia, Thailand, and Morocco show strong emerging engagement. The bibliographic coupling network reveals high internal coherence among dominant countries, especially China and India, which prioritize single-country publications. Meanwhile, Canada and Malaysia exhibit more international collaboration via MCPs suggesting varied research strategies.

These patterns mirror (Eck & Waltman, 2017) findings on citation-based domain structuring, affirming how co-citation behavior signals intellectual centrality. The observed diversity and imbalance in collaboration offer insight into national research policies and regional focus. Emerging networks like Morocco–France and Malaysia–UK highlight how developing regions seek integration into the global research discourse. Keyword networks (Figure 9) further validate this dynamic, showing co-authorship correlates with co-thematic development in many clusters.

Thematic analysis (Figures 7–13) shows how early terms like *learning styles* and *Bayesian networks* evolved into modern frameworks such as *adaptive learning*, *deep learning*, and *ChatGPT*. Keyword co-occurrence (Figure 9) and conceptual maps (Figures 10–12) reveal sustained prominence of terms like *artificial intelligence* and *personalized learning*, while also showing emergence of high-complexity concepts like *contrastive learning*, *federated learning*, and *human-centered computing*. Compared to Jing et al. (2023) and Durak et al. (2024), who treated pedagogical and technical terms as separate clusters, our study demonstrates how these elements now converge—bridging educational theory and AI practice.

Figure 11's thematic map distinguishes between motor themes (AI, adaptive learning) and declining or niche domains, offering a strategic snapshot of current research maturity. Figure 12 further visualizes longitudinal evolution by dividing timelines into conceptual phases: foundational (2001–2008), transition (2009–2016), AI integration (2017–2023), and frontier innovation (2024–2025). This phased mapping shows not just what is trending, but *when* shifts occurred. Figure 13 reinforces the hybrid nature of current discourse: keywords like *students*, *self-supervised learning*, and *adversarial machine learning* coexist, reflecting interdisciplinarity. This thematic fusion not only affirms the domain's maturity but also projects its future trajectory as both educationally impactful and technologically agile.

This study synthesizes annual output trends, source impact, geographic distribution, and thematic evolution integrating fragmented insights into a coherent analytical framework. Tools like VOSviewer and Biblioshiny enabled the mapping of intellectual structures with reproducible rigor, building on prior works (Aria et al., 2023; Aria & Cuccurullo, 2017). For researchers, the findings offer strategic entry points into active topics and networks. For institutional leaders and funders, it supports informed decisions on collaboration, innovation, and resource allocation. For practitioners, the insights outline how adaptive and personalized learning systems are evolving highlighting scalable, data-driven models aligned with future-ready education.

5. Conclusion

This study offers a comprehensive bibliometric analysis of personalized and adaptive learning research spanning 2001 to 2025, based on 922 peer-reviewed documents from the Scopus database. It maps publication trends, influential authors and sources, geographic contributions, and thematic evolution using VOSviewer and Biblioshiny. Results show a sharp rise in scholarly output after 2015, peaking in 2023, reflecting growing interest in learner-centered, AI-integrated education. Core contributors stem from computer science outlets such as *Lecture Notes in Computer Science* and *IEEE Access*, underscoring the field's technological foundation. Keyword and thematic analyses reveal a progression from early pedagogical models (e.g., learning styles) toward contemporary themes like *ChatGPT*, *federated learning*, and *reinforcement learning*, indicating the increasing integration of generative AI and data-driven personalization into educational systems.

The findings have implications for researchers, policymakers, and practitioners. For researchers, this study outlines emerging themes and identifies active contributors, institutions, and countries that can serve as collaboration targets. For policymakers and educational leaders, the trends provide evidence-based insights to guide funding priorities, innovation strategies, and international partnerships. Practitioners and developers can use the thematic evolution to align system design with current pedagogical and technological directions especially in scaling adaptive platforms using artificial intelligence. This analysis helps bridge theoretical advances and practical deployment, contributing to the broader goal of designing equitable, intelligent, and context-aware learning environments.

Despite its breadth, this study has limitations. It relies solely on the Scopus database, which, while comprehensive, may exclude relevant works indexed elsewhere. The keyword-based search strategy may also overlook interdisciplinary publications that frame personalized learning under alternate terminologies. Furthermore, bibliometric data reflect publication volume and citation patterns, but not the pedagogical impact or effectiveness of the innovations studied. Future research should incorporate mixed methods—combining bibliometric mapping with content analysis and expert evaluation—to assess knowledge gaps and the pedagogical efficacy of emerging technologies. Further exploration into the relationship between adaptive learning systems and cognitive, affective, or motivational learner factors also remains a promising direction.

6. Conflict of Interest

The authors declare that there is no conflict of interest associated with the publication of this manuscript. The research was conducted independently, without any commercial or financial relationships that could be construed as a potential conflict of interest.

7. Acknowledgments

Syamsidar Saleng conceptualized the research idea, developed the methodology, and prepared the original draft of the manuscript. Muhammad Yaumi supervised

the research process, provided critical feedback, and guided the overall theoretical framework. Sukmawati contributed to the validation of findings, assisted in the literature review, and supported the revision and refinement of the final manuscript.

The authors also acknowledge the use of ChatGPT (OpenAI) in the language editing process. This AI tool was employed to improve grammar, clarity, and sentence flow during revision. The manuscript remains an original and accurate representation of the authors' research, ideas, and intellectual contributions.

8. References

Aksu Dünya, B., & Yıldız Durak, H. (2024). Hi! Tell Me How to do it: Examination of Undergraduate Students' Chatbot Integrated Course Experiences. *Quality and Quantity*, *58*(4), 3155–3170. https://doi.org/10.1007/s11135-023-01800-x

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for Comprehensive Science Mapping Analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Aria, M., Cuccurullo, C., D'Aniello, Misuraca, M., & Spano, M. (2024). Comparative Science Mapping: A Novel Conceptual Structure Analysis with Metadata. *Scientometrics*, *129*, 7055–7081. https://doi.org/10.1007/s11192-024-05161-6

Aria, M., Le, T., Cuccurullo, C., Belfiore, A., & Choe, J. (2023). openalexR: An R-Tool for Collecting Bibliometric Data from OpenAlex. *R Journal*, *15*(4). https://doi.org/10.32614/rj-2023-089

Bancong, H. (2024). The Past and Present of Thought Experiments' Research at Glancy: Bibliometric Review and Analysis. *Discover Education*, *3*(142). https://doi.org/10.1007/s44217-024-00246-z

Cueli, M., González-Castro, P., Krawec, J., Núñez, J. C., & González-Pienda, J. A. (2016). Hipatia: A Hypermedia Learning Environment in Mathematics. *Anales de Psicologia*, *32*(1), 98–105. https://doi.org/10.6018/analesps.32.1.185641

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to Conduct a Bibliometric Analysis: An Overview and Guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Du Plooy, C., Casteleijn, D., & Franzsen, D. (2024). Personalized Adaptive Learning in Higher Education: A Scoping Review of Key Characteristics and Impact on Academic Performance and Engagement. *Heliyon*, *10*(10), e39630. https://doi.org/10.1016/j.heliyon.2024.e39630

Durak, G., Çankaya, S., Özdemir, D., & Can, S. (2024). Artificial Intelligence in Education: A bibliometric Study on its Role in Transforming Teaching and Learning. *International Journal of Technology in Education and Science (IJTES)*, *8*(1), 102–125. https://doi.org/10.19173/irrodl.v25i3.7757

Eck, N. J. V, & Waltman, L. (2017). Citation Based Clustering of Publications Using CitNetExplorer and VOSviewer. *Scientometrics*, *111*, 1053–1070. https://doi.org/10.1007/s11192-017-2300-7

Gligorea M.; Oancea R.; Gorski A.-T.; Gorski H.; Tudorache P., I.; C. (2023). Adaptive Learning Using Artificial Intelligence in E-learning: A Literature Review. *Education Sciences*, *13*(12), 1216. https://doi.org/10.3390/educsci13121216

Guo, S., Zheng, Y., & Zhai, X. (2024). Artificial Intelligence in Education Research During 2013–2023: A Review Based on Bibliometric Analysis. *Education and Information Technologies*, *29*, 16387–16409. https://doi.org/10.1007/s10639-024-12491-8

Hariyanto R., F. X. D.; K. M. (2025). Artificial Intelligence in Adaptive Education: A systematic Review of Techniques for Personalized Learning. *Discover Education*, *4*, 458. https://doi.org/10.1007/s44217-025-00908-6

Hwang, G.-J., & Chen, N.-S. (2023). Adaptive Technologies and Augmented Realities: A Section Introduction. In *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy* (pp. 2915–2917). Springer International Publishing. https://doi.org/10.1007/978-3-319-17461-7_137

Hwang, G.-J., Sung, H.-Y., Hung, C.-M., Huang, I., & Tsai, C.-C. (2012). Development of a Personalized Educational Computer Game Based on Students' Learning Styles. *Educational* Technology *Research and Development*, *60*(4), 623–638. https://doi.org/10.1007/s11423-012-9241-x

Istanti, W., Pratiwi, S., & Saddhono, K. (2024). AI-Driven Personalized Learning: Revolutionizing Language Education. *2nd IEEE International Conference on IoT, Communication and Automation Technology, ICICAT 2024*, 329–334. https://doi.org/10.1109/ICICAT62666.2024.10923274

Jhajj, G., Zhang, X., Gustafson, J. R., Lin, F., & Lin, M. P.-C. (2024). Educational Knowledge Graph Creation and Augmentation via LLMs. In A. Sifaleras & F. Lin (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 14799 LNCS* (pp. 292–304). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-63031-6_25

Jing, Y., Zhao, L., & Wang, H. (2023). Research Landscape of Adaptive Learning in Education: A Bibliometric Study on Research Publications from 2000 to 2022. *Sustainability*, *15*(4), 3115. https://doi.org/10.3390/su15043115

Koutsantonis, D., Koutsantonis, K., Bakas, N. P., Plevris, V., Langousis, A., & Chatzichristofis, S. A. (2022b). Bibliometric Literature Review of Adaptive Learning Systems. *Sustainability (Switzerland)*, *14*(19). https://doi.org/10.3390/su141912684

Le, H. T., Van Tran, T., & Nguyen, T. (2024). ODKT-IAC: Integrating Continual and Adaptive Learning for Personalized Path Recommendations. In W. Ding, L. C.-T., F. Wang, L. Di, K. Wu, J. Huan, R. Nambiar, J. Li, F. Ilievski, R. Baeza-Yates, & X. Hu (Eds.), *Proceedings - 2024 IEEE International Conference on Big Data, BigData 2024* (pp. 8136–8144). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/BigData62323.2024.10825874

Lee Y.; Lin C.-Y.; Reigeluth C. M.; Lee E., D.; H. (2021). Differences in Personalized Learning Practice and Technology Use in High and Low Performing Learner Centered Schools in the United States. *Educational Technology Research and Development*, *69*(2), 1221–1245. https://doi.org/10.1007/s11423-021-09937-y

Legowo, B., Nurhasanah, F., Saddhono, K., Budiastuti, V. I., Sutomo, A. D., & Murwaningsih, T. (2024). Enhancing Educational Outcomes Through Exploring the Optimized Options Artificial Intelligence and Deep Learning. *2024 4th International Conference on Advance Computing and Innovative Technologies in Engineering, ICACITE 2024*, 929–934. https://doi.org/10.1109/ICACITE60783.2024.10616772

Lin, F., & Chen, F. (2025). Intelligent Music Education System: Utilizing Algorithms for Personalized Learning Experience. *International Journal of High-Speed Electronics and Systems*. https://doi.org/10.1142/S0129156425402530

Lin, F., Howard, L., & Yan, H. (2022). Learning Optimal and Personalized Knowledge Component Sequencing Policies. In M. M. Rodrigo, N. Matsuda, A. I. Cristea, & V. Dimitrova (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 13356 LNCS* (pp. 338–342). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-11647-6_65

Lin, F., Morland, R., & Yan, H. (2024). QuizMaster: An Adaptive Formative Assessment System. In A. Sifaleras & F. Lin (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics):*

Vol. 14798 LNCS (pp. 55–67). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-63028-6_5

Lin, Y., Wang, S., & Lan, Y. (2022). The Study of Virtual Reality Adaptive Learning Method Based on Learning Style Model. *Computer Applications in Engineering Education*, *30*(2), 396–414. https://doi.org/10.1002/cae.22462

Mui, J., Lin, F., & Dewan, M. A. A. (2021). Multi-armed Bandit Algorithms for Adaptive Learning: A Survey. In I. Roll, D. McNamara, S. Sosnovsky, R. Luckin, & V. Dimitrova (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 12749 LNAI* (pp. 273–278). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-78270-2_49

Nanda, A. R., Nurnawaty, Mansida, A., & Bancong, H. (2025). A Bibliometric Analysis of Trends in Rainfall Runoff Modeling Techniques for Urban Flood Mitigation (2005–2024). *Results in Engineering*, *26*. https://doi.org/10.1016/j.rineng.2025.104927

Nguyen, D., Howard, L., Yan, H., & Lin, F. (2023). Adaptive Sequence Learning: Contextual Multi-armed Bandit Approach. *2023 IEEE Intl Conf on Dependable, Autonomic and Secure Computing, Intl Conf on Pervasive Intelligence and Computing, Intl Conf on Cloud and Big Data Computing, Intl Conf on Cyber Science and Technology Congress (DASC/PiCom/CBDCom/CyberSciTech)*, 751–756. https://doi.org/10.1109/DASC/PiCom/CBDCom/Cy59711.2023.10361498

Nguyen, L. M. D., Lin, F., & Chang, M. (2024). Generating Learning Sequences Using Contextual Bandit Algorithms. In A. Sifaleras & F. Lin (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 14798 LNCS* (pp. 320–329). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-63028-6_26

Nugraheni, A. S. C., Widono, S., Saddhono, K., Yamtinah, S., Nurhasanah, F., & Murwaningsih, T. (2024). Innovations in Education: A Deep Dive into the Application of Artificial Intelligence in Higher Learning. *2024 4th International Conference on Advance Computing and Innovative Technologies in Engineering, ICACITE 2024*, 785–789. https://doi.org/10.1109/ICACITE60783.2024.10616739

Nurhasanah, F., Nugraheni, A. S. C., Kusharjanta, B., Ardiansyah, R., Widono, S., & Saddhono, K. (2024). A Design of Virtual Classrooms Through AI, ML and DL to Improve the Level of Learning. *2024 4th International Conference on Advance Computing and Innovative Technologies in Engineering, ICACITE 2024*, 940–945. https://doi.org/10.1109/ICACITE60783.2024.10616641

Rezai, A., Namaziandost, E., & Hwang, G.-J. (2024). How Can ChatGPT Open Promising Avenues for L2 Development? A Phenomenological Study Involving EFL University Students in Iran. *Computers in Human Behavior Reports*, *16*. https://doi.org/10.1016/j.chbr.2024.100510

Saddhono, K., Judijanto, L., Mulyaningsih, I., Zaki, R. M., Rintaningrum, R., & Anoegrajekti, N. (2024). Teaching Literature with AI: Enhancing Education Through Automated Analysis and Interpretation. *2nd IEEE International Conference on IoT, Communication and Automation Technology, ICICAT 2024*, 742–747. https://doi.org/10.1109/ICICAT62666.2024.10923037

Saddhono, K., Suhita, R., Istanti, W., Kusmiatun, A., Kusumaningsih, D., & Sukmono, I. K. (2024). AI-Powered Language Learning: Enhancing Literacy in the Digital Age. *2024 4th International Conference on Advancement in Electronics and Communication Engineering, AECE 2024*, 856–861. https://doi.org/10.1109/AECE62803.2024.10911149

Saddhono, K., Suhita, R., Rakhmawati, A., Rohmadi, M., & Sukmono, I. K. (2024). AI and Literacy: Developing Critical Thinking and Analytical Skills in the Digital Era. *2nd*

IEEE International *Conference on IoT, Communication and Automation Technology, ICICAT 2024*, 360–365. https://doi.org/10.1109/ICICAT62666.2024.10922871

Strousopoulos, P., & Troussas, C. (2024). Personalized Learning Via Gamified Virtual Environments: Exploring Insights and Impact. *Proceedings - 2024 19th International Workshop on Semantic and Social Media Adaptation and Personalization, SMAP 2024*, 111–115. https://doi.org/10.1109/SMAP63474.2024.00029

Sung, H.-Y., Hwang, G.-J., Hung, C.-M., & Huang, I. (2011). A learning style perspective to investigate students' perceptions in choosing the most-beneficial educational systems. *Proceedings of the 19th International Conference on Computers in Education, ICCE 2011*, 198–205. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84860437345&partnerID=40&md5=2a48452fc91446a9989ef03b87bbdb13

Troussas, C., Krouska, A., Mylonas, P., Sgouropoulou, C., & Voyiatzis, I. (2025). Fuzzy Memory Networks and Contextual Schemas: Enhancing ChatGPT Responses in a Personalized Educational System. *Computers*, *14*(3). https://doi.org/10.3390/computers14030089

Visser, M., van Eck, N. J., & Waltman, L. (2021). Large-scale comparison of bibliographic data sources: Scopus, Web of Science, Dimensions, Crossref, and Microsoft Academic. *Quantitative Science Studies (QSS)*, *2*(1), 20–41. https://doi.org/10.1162/qss_a_00112

Wang., X., Huang., R. T., & Martin., F. (2024). The Efficacy of Artificial Intelligence Enabled Adaptive Learning Systems: A Meta Analysis. *Journal of Educational Multimedia and Hypermedia*. https://doi.org/10.1177/07356331241240459

Wongwatkit, C., & Panjaburee, P. (2024). A Duplex Adaptation Mechanism in the Personalized Learning Environment. *Journal of Computers in Education*, *11*(4), 1111–1131. https://doi.org/10.1007/s40692-023-00292-w

Xie, H., Chu, H.-C., Hwang, G.-J., & Wang, C.-C. (2019). Trends and Development in Technology Enhanced Adaptive/Personalized Learning: A Systematic Review of Journal Publications from 2007 to 2017. *Computers and Education*, *140*. https://doi.org/10.1016/j.compedu.2019.103599

Yang, T.-C., Hwang, G.-J., Chiang, T. H. C., & Yang, S. J. H. (2013). A Multi-dimensional Personalization Approach to Developing Adaptive Learning Systems. *Lecture Notes in Computer* Science *(Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *7947 LNCS*, 326–333. https://doi.org/10.1007/978-3-642-39146-0_30

Zhao, L., Liu, Z., & Zhao, X. (2025). Developing a Knowledge Graph for Intelligent Structural Design Course. *Proceedings of 2024 3rd International Conference on Artificial Intelligence and Education, ICAIE 2024*, 123–128. https://doi.org/10.1145/3722237.3722259

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. Organizational *Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629