SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 8889-8907
Open Access. Online & Print

DOI: 10.5281/zenodo.19865847

ADAPTIVE E-LEARNING - BASED ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION: A BIBLIOMETRIC ANALYSIS STUDY

Ahmed Said Salem Elattar[1], Mukhaled Hamza Hussein Abass Al-Khafaji[2], Mohamed Shawky Hozaifa[3], Esam Shawky Elzok[4*], Mohammed Alsuwailem[5,] Basant A. Alakabawy[6] and Basma Alakabawy[7]

[1]Associate Professor of Educational Technology Department of Educational Technology- Faculty of Specific Education- Menoufia University Shebin El-Kom, Menoufia Governorate, Egypt. Email: ahmed.elatar@sed.menofia.edu.eg Orcid ID: https://orcid.org/0000-0001-9792-4354
[2]Environment Pollution Department, College of Environment, Al-Qasim Green University, Babylon 51013, Iraq, mukhaled.hamza@environ.uoqasim.edu.iq, http://orcid.org/0009-0009-4960-5661
[3]Associate Professor of Educational Technology, Faculty of Specific Education - Menoufia University, Tala, Menoufiy,Egypt, ORCID: http://orcid.org/0009-0007-4509-2374 , mohamed.hozaifa@sed.menofia.edu.eg
[4]Professor of Educational Technology, Faculty of Specific Education – Menoufia University, Shebin-Elkom, Menoufiy, Egypt, http://orcid.org/0009-0006-4129-3075, essam.shebl@sed.menofia.edu.eg
[5]Associate Professor, Faculty of Education - Qassim University Al-Qassim, Kingdom of Saudi Arabia, https://orcid.org/0009-0006-0485-3192, M.alsuwailem@qu.edu.sa
[6]Associate Professor of Media and Children's Culture, Faculty of Early Childhood Education - Menoufia University, Shebin-Elkom, Menoufiy, Egypt, http://orcid.org/0009-0008-8263-0570, drbasantalakabawy@gmail.com
[7]Assistant Professor of Educational Technology, Faculty of Specific Education - Menoufia University, Menoufiy, Egypt, https://orcid.org/0009-0000-2991-2167, bosyalakabawy@yahoo.com

Received: 15/02/2026
Accepted: 18/03/2026

Corresponding Author: Esam Shawky Elzok (essam.shebl@sed.menofia.edu.eg)

ABSTRACT

The rapid development of AI and machine learning-based e-learning has gained significant momentum due to its potential to transform into adaptive e-learning (AEL). As a result, AEL has drawn the attention of higher education sectors to leverage its capabilities in providing education at all times. This dynamic requires knowledge of integrating AI into adaptive learning environments and systems to achieve learning outcomes. The study aims to analyze publications on AEL in higher education, focusing on its bibliometric characteristics. Data were collected from the Scopus database, revealing 5168 publications on the study topic from 2014 to 2024. 2789 published articles were analyzed using VOSviewer. The results of the study were presented based on quantitative analysis. Tables, graphs and visual maps were used to highlight important indicators of article production and citations. There was a steady increase in publications on AEL between 2014 and 2023. The results showed that AEL is a step towards personalized learning. Despite challenges such as the complexity of AI systems, the findings demonstrate the potential of adaptive e-learning to meet the

unique needs of learners. The analysis highlights the multidimensional nature of AI-based adaptive e-learning, the interdisciplinary nature of publication venues, and unexplored research areas. The results of the analysis are integrated with relevant literature reviews. In summary, this research provides valuable insights for interested scholars to understand the current state of AEL research and identify future research opportunities in this dynamic field.

KEYWORDS: Adaptive e-learning, Artificial intelligence, Bibliometric Analysis, Higher Education, Scopus, VOSviewer.

1. INTRODUCTION

The need for adaptive e-learning (AEL) has increased steadily due to its ability to meet individual needs, personalize learning, and ensure continuity of education at all times. Therefore, AEL has attracted the interest of education professionals in attempts to benefit from its potential within higher education sectors (El-Sabagh, 2021). The e-learning model based on designing learning for a specific group of teachers which may not be suitable for other learners has cracked (Szymkowiak et al., 2021). In addition to the lack of flexibility and designing content without taking into account the learners' abilities (Elmaadaway & Abouelenein, 2023). AEL has the potential to revolutionize by offering alternatives to many of the challenges of traditional e-learning, such as flexible access to content, personalized learning and learner freedom (Ajeel, 2022). Therefore, learning in higher education must be adapted. Because AEL is no longer a forced choice, but rather a pedagogical methodology based on leveraging emerging technologies while recognizing the unique learning styles of learners (Ilić et al., 2023).

Higher education faces many problems, including the frequent increase in the number of students, epidemics, war zones, and student unrest(Wang, 2024). This highlights the urgent need for adaptive learning techniques to respect the unique learning style of each student. Which are innovative tools that customize educational experiences to meet the needs of individual learners (Chalkiadakis et al., 2024). In addition to investing in infrastructure, developing high-quality web-based courses, Creating awareness, training teachers and learners, and addressing equity concerns to transform learning (Chen, et al., 2023; Ahmed & Ibrahim, 2023). AEL can be a powerful tool for transforming education, contributing to transformative learning experiences for students (Krechetov & Romanenko, 2020). This brings about the need for greater adoption and integration of AEL approaches that may offer transformative empowerment. AEL can help: transcending physical boundaries, providing inclusive education, personalizing learning, promoting deep engagement, and encouraging self-exploration (Truong, 2016; Qu & Ogunkunle, 2021).

On the other hand, we cannot ignore the difficulties that may be encountered in the mechanism of overcoming the digital divide and fostering human communication (Sanders& Scanlon, 2021). Good educational communication on the Internet requires knowledge of the content and equipment for an effective adaptive learning environment (Rincon-Flores et al., 2024). Strategic partnerships investing in infrastructure and developing digital pedagogy competencies for teachers can revolutionize AEL and make it an entry point for access and personalization for all learners in the future (Yu et al., 2024). Here, there is an urgent need to enhance solutions and put them into practice by exploring non-traditional approaches, and adopting adaptive delivery in higher education (Alenezi et al., 2023).

Bibliometric analysis is a quantitative method that can help identify previous literature, current developments and gaps in the evolving environments of AEL (Passas, 2024). The current research will not only map the major trends and emerging areas, but also seek to explore the real impact and knowledge gaps that require further research and study. By accessing global perspectives and influential voices in future research agendas and decisions, the research has the potential to guide academics, researchers, and policymakers seeking to navigate the future of education in an AI-driven world. In addition, it provides a holistic view of the developments that have occurred in the field of AEL in the past. On the other hand, this paper can pave the way for a more efficient and effective adaptive learning environment that achieves equity and personalized access for all. The research aims to conduct a systematic study of the scientific literature to identify patterns, trends and impact in the field of AEL using bibliometric analysis to generate meaningful information such as finding the main topics, authors, sources, most cited articles and collaborations. In addition to knowing the conceptual, intellectual and social structure of the literature on this topic, and determining a knowledge base for the use of AEL in higher education in a large-scale and integrated manner with teaching and learning processes. By providing a set of reliable instructions as an alternative to systematic literature reviews. Thus, the research questions addressed by this study are as follows:

1. In terms of the current status and research trends in AI-based AEL, what are the most cited articles, leading journals, leading authors, research topics, keywords, and countries that contribute the most to research production in this field?
2. In terms of future research ideas, what topics and themes could future studies and research include?

2. LITERATURE REVIEW

Research trends can be highlighted by examining the research topics and themes of the articles. Many

scholars have mentioned the importance of reviewing published research. In this regard, Amobonye et al., (2024) pointed out that reviewing published articles can provide a comprehensive analysis of current and future studies, and they stated that it is useful to discuss the implications of the results of the analysis.

Several bibliometric analysis-based reviews of adaptive learning have been conducted. For example, Fadieieva (2023) conducted a bibliographic analysis of adaptive learning literature (n = 344) in the field of social sciences published from 2011 to 2019. The study used the Scopus database to identify relevant sources and employed cluster analysis based on the co-occurrence of keywords to classify key concepts, highlighting their development and impact during the specified period. Koutsantonis et al., (2022) also performed a computational analysis of articles published in the field of adaptive learning during the period 1992-2021, obtained from the Scopus database. 5564 papers were analyzed in multiple categories (conference papers, articles, book chapters, editorials, letters, etc.) to construct bibliometric maps of keywords, authors, and references. The paper found the 100 most common keywords in the database, in the order of their appearance, grouped in the bibliometric map and time series. Jose et al., (2024) conducted a bibliometric analysis of developments, trends, and themes in adaptive learning systems for American Sign Language. A wide range of data from Web of Science and Scopus was used. 833 documents were extracted between 1969 and 2023 from 501 different sources from Scopus. The paper highlights the growing scholarly output and identifies key contributors and influential works. This underscores the growing recognition of the importance of adaptive learning systems due to technological advancements. Kurniawan & Kusumaningrum (2021) also reviewed studies on adaptive learning from 2011 to 2021 (n = 8475). The findings of these studies revealed that adaptive learning has become an important trend in educational technology research. The study indicated that there is a need to identify and analyze the trends and developments of research related to adaptive learning to understand the interest of researchers in the topic. On the other hand, Güngören et al. (2024) conducted a study to identify trends in research in the field of adaptive learning. Articles were analyzed using bibliometric techniques in the Web of Science Core database. Out of 2136 publications, 392 publications were identified and included in the analysis. The study found that trends related to adaptive learning are evolving, and different variables are gaining importance in the context of adaptive learning. Therefore, it is of great importance to consider these trends when designing new studies and creating new adaptive learning environments. The results obtained in this study should be supported by further research that compares and examines different trends and their effects.

The results of these studies have revealed that adaptive learning has become an important trend. With the rapid development of artificial intelligence and other technologies in recent years, there have been many breakthroughs in adaptive learning. Therefore, it is necessary to gain insight into the development of related research and track the research frontiers to promote its further development, especially over the past two decades. Here, the research aims to identify the most productive literature on AEL in higher education. Explore the main authors in this field, especially with the steady development of adaptive learning research. In addition to the main research forces to clarify the topics of most concern to researchers, the main country of publication in this field, publishing journals, and identifying keywords in the field. In addition, research into topics and themes that could be addressed in future research in this area.

3. RESEARCH METHODOLOGY

Bibliometric methodology is the use of quantitative methods, such as author analysis, citation analysis, or keyword analysis, for bibliometric data(Öztürk, et al., 2024). Today, bibliometrics has become the center of the internal logical structure of information science, with the advantage of performing quantitative and intuitive analysis of the literature using knowledge mapping and cluster analysis(Linnenluecke et al., 2020). It can be said that bibliometric analysis supports the development of a certain field from multidimensional perspectives, such as sorting the current state of research in the field, tracking research trends, and presenting the main research forces) Bhaiswar et al., 2021).

The methodology used in this study is comparable to that of the studies of Tandon et al. (2021), Makda (2024), and Phan et al. (2022). These studies served as the framework to identify, screen, and analyze articles and conference papers that explore AEL in higher education to compile a relevant and applicable dataset. The search mainly relied on the bibliometric method using VOSviewer to map key papers on AEL in the Scopus database. The database was chosen due to its broad coverage of

journals(Hallinger & Nguyen, 2020). Two main steps were followed: first, search terms and search strings were used to find relevant literature in the Scopus database; second, specific inclusion and exclusion criteria were applied to extract only relevant and applicable literature for bibliometric analysis.

3.1. Data collection

The first step in retrieving data in a bibliometric study is to select the database and the specific index used in the research. The research selected the Scopus database as the data source. The time period for this study was set from 2014 to 2024. The reason for choosing this time period as the data source is that although AEL has emerged, it has not been applied for a long period of time due to immature technology and application cost. With the emergence of online learning and artificial intelligence, AEL has become better supported externally, and systematic research on AEL began to emerge at the beginning of this century(Alakabawy, 2024).

The keywords were used to search the literature. "AEL", "Adaptive e-training", "Adaptation Models", "Adaptive behavior", "Adaptive Boosting", "Adaptive Support Systems", "Adaptive Learning", "Intelligent tutoring System", "Adaptive Hypermedia", "Adaptive Learning Environment", "Adaptive learning Systems", "Higher Education", "Uni".

Tuesday, July 30, 2024, saw the use of the following search term to perform an advanced search:(TITLE-ABS-KEY ("AEL" OR "Adaptive e-training" OR "Adaptation Models" OR "Adaptive behavior" OR "Adaptive Boosting" OR "Adaptive Support Systems" OR "Adaptive Learning" OR "Intelligent tutoring System" OR "Adaptive Hypermedia" OR "Adaptive Learning Environment", "Adaptive learning Systems" AND TITLE-ABS-KEY ("Higher Education" OR "Uni")). 5168 publications were found in the initial search. Many publications from the initial search had misleading results. In other words, not all publications were written in English. The category of publications was not limited to articles or conference papers. Not all publications were closely related to the topic. Therefore, the inclusion and exclusion criteria were used in Table 1.

Table 1: Inclusion And Exclusion Criteria Were Used.

Standards	Adjust the search parameters
The year	2014–2024
Topic Area	Computer Science, Social Sciences, Arts and Humanities
Type of Document	Article and Conference Paper
Speech	English
Type of Source	Journal, Conference Proceeding

3.2. Data Filtering

The criteria applied are as follows: The final search query used to perform the advanced search with all refinements was as follows: (TITLE-ABS-KEY ("AEL" OR "Adaptive e-training" OR "Adaptation Models" OR "Adaptive behavior" OR "Adaptive Boosting" OR "Adaptive Support Systems" OR "Adaptive Learning" OR "Intelligent tutoring System" OR "Adaptive Hypermedia" OR "Adaptive Learning Environment", "Adaptive learning Systems" AND TITLE-ABS-KEY ("Higher Education" OR "Uni")) AND PUBYEAR 2014 AND PUBYEAR 2024 AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ARTS")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) AND (LIMIT-TO (LANGUAGE, "English")).

After applying the acquisition criteria, a total of 2789 papers were obtained. The results and conclusions were arranged and presented by: annual publication numbers, publications by country, widely cited articles, publications by source, authorship distribution, co-authorship patterns, and keyword co-occurrence network. VOSviewer, a powerful and intuitive review tool for data analysis and visual interpretation via interactive maps (Van Eck & Waltman, 2011), was used. This software facilitates the visualization of bibliometric networks by displaying relationships and connections within a visual network. Figure 1 provides an overview of the research paper selection process.

4. DATA ANALYSIS

2789 publications on AEL were included. Of these, 1267 were journal articles and 1523 were conference articles. They were examined in terms of publication year, country, document source, source title, author, and co-author network. In addition, keywords and most cited publications were analyzed.

4.1. Publications per year

Research in this area has expanded rapidly in recent years. This is evident from the doubling of publications to (395) in 2021, up from (273) articles in 2020. While in 2023 it was (417). This pattern indicates a strong field with continued development and active exploration. It is worth noting that there are currently (230) publications for 2024, and there is a good chance that this number will increase in the last quarter of the year. Figure 2 provides an illustration of this. The field of AEL considers

personalized learning that takes into account learners' needs, characteristics, learning styles, and learning preferences. This has prompted higher education institutions to rapidly investigate, test, and implement AEL (Fadeeva, 2023; Gligoria et al., 2023;). Therefore, there is a need for a greater understanding of AEL practices. This is highlighted by the growing research interest that is consistent with the growing global acceptance of these practices across higher education institutions. In 950 (34%) of the articles, the terms "adaptive" or "personalized" are found. Research in this area is now focusing on access to AEL rather than traditional e-learning.

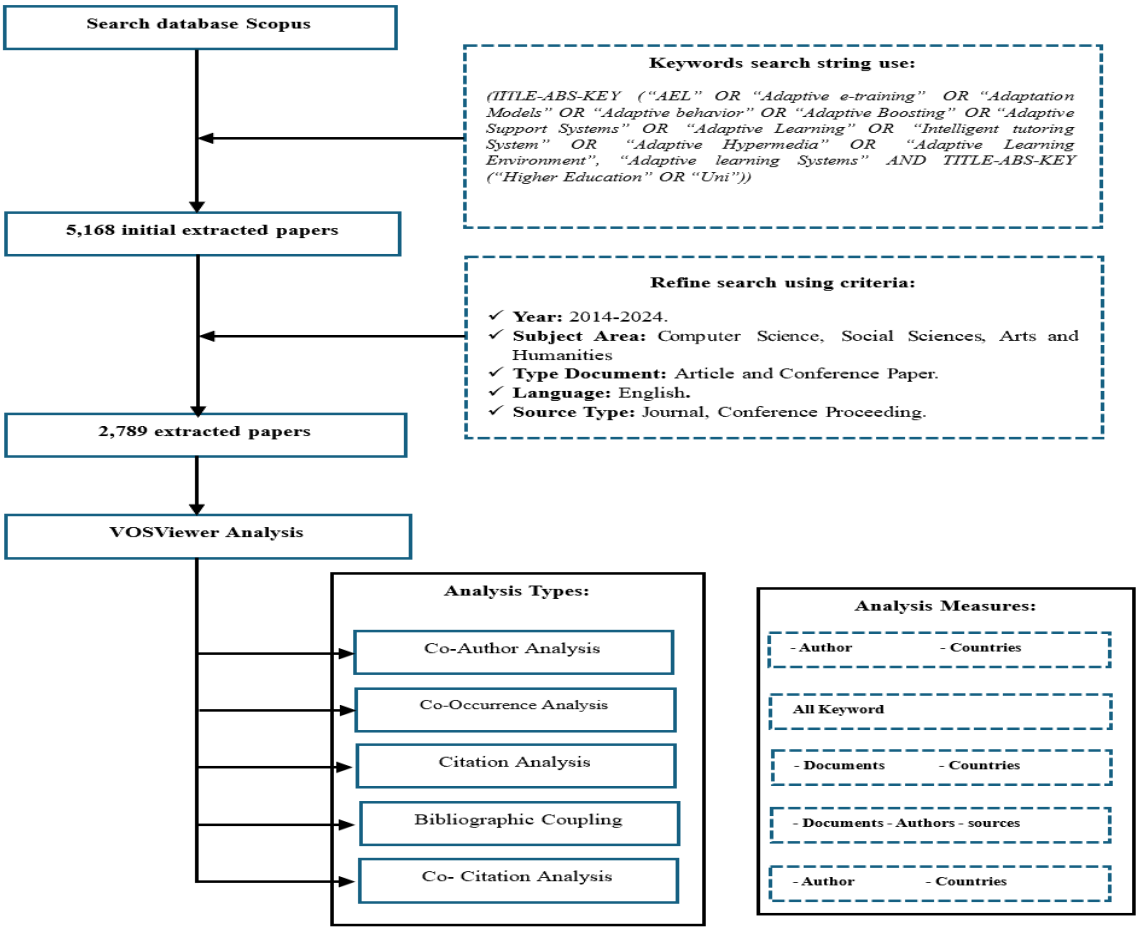

Fig 1: Process of selecting research papers.

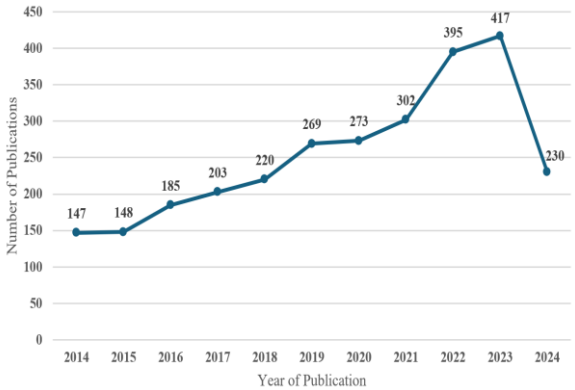

Fig. 2: Annual Publications.

4.2. Publications by country

The number of publications per country was determined. For this analysis, countries that produced five or more articles on AEL were considered. China led the field with 617 publications and 8,199 citations. The United States came in second with 424 publications and 7,207 citations. Table 2 lists the top 20 nations according to citations and publications.

Table 2: Citations and publications by nation.

Nation	Publications	Citations
China	617	8199
United Status	424	7207
Singapore	198	978
Australia	137	2253
India	136	1817
Canada	87	2049
Saudi Arabia	84	1048
Hong Kong	79	996
Germany	37	1212
South Korea	44	795
Spain	50	1790
Pakistan	96	653
Italy	41	832
Malaysia	69	475
Japan	51	323
Netherlands	68	906
France	46	730
United Arab Emirates	66	163
Vietnam	17	271

Figure 3 shows the countries where at least five publications on AEL have been published.

Figure 3 shows that most of the research on AEL is conducted in Asia, America and Europe. There are fewer articles in African countries. In line with the trends of personalization of learning and taking into account the learner model through AEL, there is a pressing need for more research on AI-powered AEL in Africa, especially given the distinct contextual conditions of emerging countries (Kosak et al., 2022; Martinez et al., 2009; Moores et al., 2021).

4.3. Publications by document source title

Table 3 shows the top 10 journals by the density of publication of articles related to AEL. The first journal with publications in this field was the International Conference Proceedings Series (98 papers, 412 citations). This could be an indication of the benefits of AEL in sustainable and continuing education. The second most popular journals were IEEE Access (63 papers, 999 citations), Computer and Education (24 papers, 1943 citations), Education and Information Technologies (16 papers, 501 citations), and British Journal of Educational Technology (15 papers, 319 citations).

Table 3: Citations and Publications for each source.

Source	Publications	Citations
International Conference. Proceeding Series.	98	412
IEEE Access.	63	999
Ceur Workshop Proceedings	84	221
Neurocomputing	26	524
Computer and Education	24	1943
Education and Information Technologies	16	501
British Journal of Educational Technology	15	319
International Journal of Artificial Intelligence in Education	11	362
International Journal of Emerging Technology in learning.	11	362
Journal of Theoretical and Applied Technology	6	20

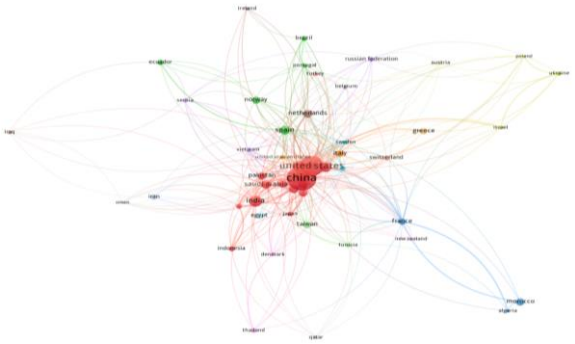

Fig. 3: Nations where at least five recent articles on AEL have been made.

Figure 4 shows an overview of publications and citations for each of the top 10 sources on AEL.

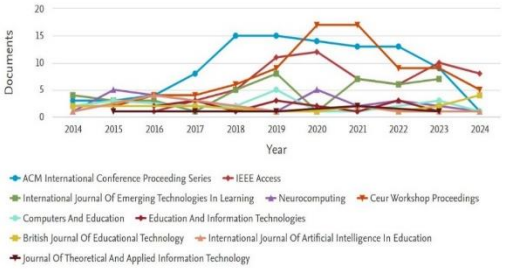

Fig. 4 publications and Citations per Source title for up to Top 10 Source about AEL.

4.4. Most Cited Publications

Table 4 shows the 15 publications (out of 2789 publications) that received more than 60 citations. The most cited documents and their resulting focus areas were taken from the papers. The analysis of these papers was required to find out the research area conducted in AEL. The focus areas were limited to the following keywords:

- • AEL. • Adaptive e-training. • Adaptive learning systems.
- • Intelligent tutoring systems. • Recommendation system. • Personalized learning.
- • Adaptive e-support. • Adaptive multimedia. • Adaptive learning environment.
- Adaptive online learning.

AI applications in higher education are constantly evolving. However, research and experiments on AI-powered AEL are still in their early stages. This requires an awareness of the aspects of AEL and future studies on this topic. In addition to its impact on students, teachers, and educational institutions. Potential research topics include AI-powered adaptive learning (Moneo et al., 2022). To improve personalization and effectiveness, future research in AEL should focus on leveraging AI, eye tracking, and learning analytics technologies (Fadeeva, 2023).

On the other hand, designing AEL systems based on learners' learning styles should be a top priority for developers to personalize courses (Iyer & Debang, 2023). Investigating the automatic extraction of micro-learning items (MLOs) from lecture videos to facilitate presentations so that they are more adaptable and flexible. It contributes to improving the level of teaching in AEL contexts (Atef, et al., 2022). Furthermore, it is essential for teachers to receive continuous digital professional development in information technology, personalized learning environment, and artificial intelligence applications to successfully adopt adaptive learning systems in higher education institutions (Taylor et al., 2021). In light of this, future studies can consider improving AEL systems and increasing their effectiveness, which will enhance innovation and lifelong learning. Furthermore, future research can be conducted that takes into account the learner model through the following variables: intellectual ability, cognitive load, achievement motivation, self-efficacy, multiple intelligences, locus of control, virtual agent technology, semantic web, ontology models, eye tracking and multiple dimensions (cognitive, educational, systemic and social) (Pera et al., 2024).

Table 4 Top cited publications (> 60).

Title	Cited	Study type	Method	Data Source	Keywords
Integrating learning styles and AEL system: Current developments, problems and opportunities	339	Qualitative	Review	literature review	Computer aided instruction; Students; Teaching; AEL systems; E-learning environment; Integration process; Learning Style.
Identification of personal traits in adaptive learning environment: Systematic literature review.	168	Qualitative	Review	literature review	Computer aided instruction; Navigation; Adaptive learning environment; Adaptive learning systems; Cooperative/collaborative learning; Intelligent tutoring system; Systematic literature review.
QuizBot: A Dialogue-based Adaptive Learning System for Factual Knowledge.	125	Mixed Methods	Exploratory Study	Questionnaire, Interview	Human computer interaction; Human engineering; Intelligent systems; User interfaces; Adaptive learning systems; Chatbots; Conversational agents; Educational Applications; Factual knowledge; Learning gain; Pedagogical agents; Students.

A method of anomaly detection and fault diagnosis with online adaptive learning under small training samples	114	Qualitative	Case Study	Observations	Classification (of information); Computer aided diagnosis; E-learning; Failure analysis Adaptive learning; Anomaly detection; Artificial Immune System; Classification functions; Clustering; Mutually independents; Small training; Training sample; Fault detection.
An online adaptive learning environment for critical-thinking-infused English literacy instruction	110	Quantitative	experimental study	Tests	Computer aided instruction; Students; Teaching; Adaptive instruction; Adaptive learning environment; Critical thinkings; Language learning; Online discussions; Teaching and learning; E-learning.
Adaptive learning path recommender approach using auxiliary learning objects	106	Qualitative	Case Study	Observations	e-learning; Factorization; Quality control; Item response theory; Learning objects; Learning paths; Long-term goals; Matrix factorizations; Learning systems.
AEL environment based on learning styles and its impact on development students' engagement	106	Quantitative	experimental study	Tests	AEL environment; learning styles; students' engagement.
The review of the adaptive learning systems for the formation of individual educational trajectory.	92	Qualitative	Review	literature review	Adaptive systems; E-learning; Industrial research; Integration; Knowledge management; Adaptive learning systems; Comparative analysis; Institutions of higher educations; Intellectual development; Knowledge assessment; Learning and teachings; Learning management system; Modern technologies.
Adaptive learning: Helpful to the flipped classroom in the online environment of COVID?	90	Qualitative	Review	literature review	E-learning; Learning systems; Motivation; Students; Adaptive learning; Classroom environment; COVID; Flipped classroom; Online environments; Potential difference; Student perceptions; Numerical methods.
An AEL system for enhancing learning performance: Based on dynamic scaffolding theory.	89	Quantitative	experimental study	Tests	AEL system; enhancing learning; performance; dynamic scaffolding theory
A robust classification to predict learning styles in AEL systems	72	Qualitative	Review	literature review	AEL; systems Felder-Silverman learning style; model Fuzzy.
Assessment of the influence of AEL on learning effectiveness of primary school pupils	69	Quantitative	experimental study	Tests	AEL; Bloom's taxonomy; Cognitive computing; Learning analytics; Learning effectiveness; Primary education
Learning content design and learner adaptation for AEL environment: a survey	68	Qualitative	Review	survey	AEL; Learner adaptation; Learning content design; Learning object; Learning path.
Rule based adaptive user interface for AEL system	66	Quantitative	experimental study	Tests	Adaptive user interface; Adult learning; Intelligent tutoring systems; Interactive learning environments; Multimedia/hypermedia systems.
Prediction of Learner's Profile Based on Learning Styles in AEL System	64	Qualitative	Review	literature review	back propagation neural network model; Felder-Silverman learning style model; Fuzzy C means.

4.5. Author& co-authorship network publication

Co-author analysis sheds light on the collaborative networks that support research in an area(Carchiolo et al., 2022). Of the 2278 publications, the number of authors was 8544. This included both co-authors and original authors. The minimum number of papers per author was set at two. In light of this, 939 authors were found to be either solo or co-authors. Figure 5 shows the network of authors, whether they were independent or in groups of co-

authors.

set at two. In light of this, 939 authors were found to be either solo or co-authors.

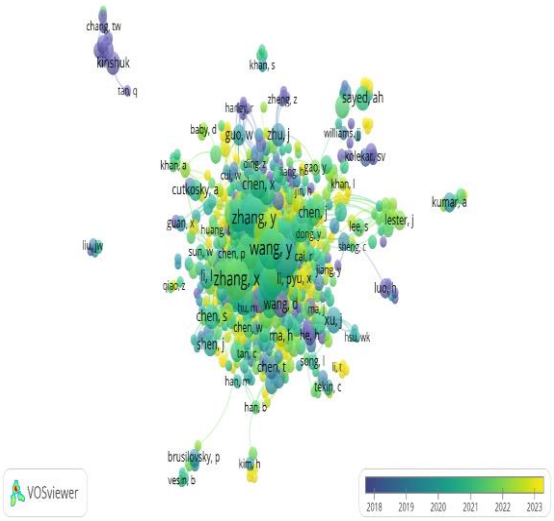

Figure 5 shows the network of authors, whether they were independent or in groups of co-authors.

Fig. 5 Overlay visualization co-authorship network. Table 5 shows a sample of the publication records of the top 10 authors during the specified period, ranked by citations.

Table 5: Authors' extract based on each author's total number of publications (both as a solo and co-author).

Author	Publications	Citations
Wang, Y.	8	249
Zhan, X.	8	176
Wang, I.	7	292
Zhang, H.	6	697
Zhan, Y.	6	495
Zhan, J.	5	84
Wang, Z.	5	335
Liu, Y.	4	161
Chen, I.	4	177
Li, Y.	3	117

The works of Wang, Y (8 papers, 249 citations), Zhan, X (8 papers, 176 citations) were widely published. This was followed by the works of Wang, I. (7 papers, 292 citations), Zhang, H. (6 papers, 697 citations), Zhan, Y. (6 papers, 495 citations), and Zhan, J. (5 papers, 84 citations). One limitation of the analysis was that all publishing author names are stored in a single column of the author data retrieved by VOSviewer from Scopus. This results in the total number of citations per text rather than per author. For example, in the sample in Table 5, Zhang, H. had a total of 23 publications and 697 citations. Globally, authors publishing in AEL are indicated in yellow (Sweileh, 2021). Many authors were represented from 2018 to 2023, which may indicate that studies in this area are concentrated in personalized learning.

4.6. Co-occurrence keyword analysis

Conducting a co-occurrence keyword analysis is essential to identify trends in the literature (Narong& Hallinger, 2023).This research examines the frequency with which certain keywords appear together in the previously obtained literature. Creating a co-occurrence map of the extracted keywords and classifying them appropriately can provide an explanation for the research on AEL(Wijaya et al., 2023). On the other hand, this focused analysis helps to find themes, topics, correlations, trends, and research gaps.

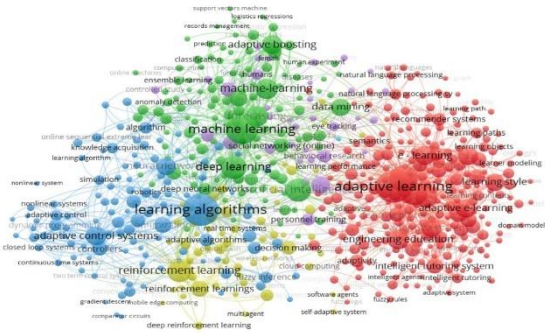

Fig. 6: Map of networks showing co-occurring terms

4.6.1. Cluster 1 Adaptive Learning Technology

The map displays 246 keywords in red. The strong focus was on learning management systems, adaptive tools for delivering and managing adaptive content. This cluster emphasizes the role of AEL in personalizing learning and delivering personalized learning. Most of the terms such as "AEL", "adaptive e-training", "AEL systems", "adaptive e-support", "personalized learning", "recommendation system", and "intelligent tutoring systems" indicated that adaptive learning is an important approach because it provides individualized education that takes into account each student's unique learning style.

On the other hand, terms such as "individualized learning," "personalized learning," "adaptive platform," "pedagogy," and "engagement" have referred to different themes related to effective approaches to learning in an adaptive environment. This may indicate that the use of interactive learning increases student happiness and engagement (Marín-Vinuesa& Rojas-García, 2024). In addition, keywords such as "adaptive testing," "adaptive assessment," "adaptive feedback," "adaptive scaffolding," and "student engagement" were found. These indicate that there is an investigation into assessing and enhancing learning outcomes in AEL. Keywords such as "adaptive testing," "adaptive assessment,"

"adaptive feedback," "adaptive scaffolding," and "student engagement" were also found. These refer to the investigation of assessing and enhancing learning outcomes in AEL.

In addition to keywords such as "meta-analysis," "mixed method," "qualitative research," and "quantitative research," qualitative research was a significant proportion of the publications in this group examining consumer views and interactions with adaptive learning environments. Terms such as "lockdown," "emergency remote teaching," and "COVID-19" drew attention to how the COVID-19 pandemic has impacted adaptive learning. This suggests that the study of online adaptive learning may be necessary in the face of unforeseen events. In addition to keywords such as "meta-analysis," "mixed method," "qualitative research," and "quantitative research," qualitative research was a significant proportion of publications in this group examining consumer views and interactions with adaptive learning environments. Terms such as "lockdown," "emergency remote teaching," and "COVID-19" drew attention to how the COVID-19 pandemic has impacted adaptive learning. This suggests that studying adaptive online learning may be necessary in the face of unforeseen events. Examining specific pedagogies and digital technologies that can be effectively applied to enhance learning outcomes and student engagement in adaptive learning would be useful.

4.6.2. Cluster 2 Development of educators

The green area in this Cluster of maps included 125 terms. Keywords such as "deep learning," "individualized learning," "personalized learning," "motivation," and "learner autonomy" showed that AEL focuses on key elements of the adaptive learning process that relate to teaching and learning techniques and strategies. On the other hand, it highlights the need to equip educators with the competencies to create and implement flexible adaptive learning environments(Peng et al., 2019). Thus, terms that focus on educators' professional development emerged, such as "career advancement," "teacher development," "training," "adaptive training," "academic skills development," and "instructional design skills.".

This emphasizes the relationship between educators' professional development and teaching methods for adaptive environments, and the need for educational initiatives that address the opportunities and challenges posed by AEL(Christodoulou & Angeli, 2022). This agrees with Roddy et al. (2017) that it is essential for educators to have the skills and knowledge to deliver instruction in adaptive online learning environments. Keywords such as "adaptive assessment," "adaptive evaluation," "adaptive feedback," "adaptive activities," "adaptive e-tests," "student-centered activities," and "student satisfaction" were found in the first cluster. This indicates the need to pay attention to evaluation, assessment, and enhancing learning outcomes in adaptive environments. This cluster represents the role and influence of educators in the field of AEL when it comes to developing assessments(Bower et al., 2024). To create learning experiences, it is important to build teachers' academic expertise in managing AEL systems(Suh et al., 2024).

On the other hand, the keywords "learning resource management", "adaptive learning systems management", "adaptive support and tutoring management", and "adaptive content management" appear to support terms such as "machine learning", "learner behavior modeling", "visual modeling", "learning paths", "domain model", "adaptive model", and "learner model" in the results of the first group analysis. Because they show that improving higher education requires the use of AI technology. This highlights the role of AI-powered adaptive learning in addressing teacher shortages, enabling professional development, and providing an "expert model" that distributes adaptive content based on the unique learning preferences and characteristics of each student(Ezzaim et al., 2023). In light of the analysis of this group, it may be useful to conduct studies on the competencies and professional development programs for assessment procedures and motivation of higher education students and their performance as requirements for AI-based adaptive learning.

4.6.3. Cluster 3 governance, policy, and management

In the blue area of the map, 110 keywords were found. Keywords such as "institutional governance," "regulations," "decision-making," "innovation," and "quality assurance" indicate that this group focuses on leadership and the context of adaptive learning in higher education. This highlights the need for laws and leadership frameworks that support innovation, inclusion, and quality control in AEL(Chughtai et al., 2024). From another perspective, these keywords highlight the need for effective governance and policy development to oversee the integration of AEL technologies. Keywords such as "institution," "university," "higher education," "administration," and "subjects" were also found. These relate to how higher education institutions respond to the

opportunities and challenges posed by AEL. This points to the relationship between "policy" and "innovation" that requires a focus on developing regulations that promote and fund innovative approaches to AEL.

Keywords such as "institution," "university," "higher education," "administration," and "subjects" were also found. These relate to how higher education institutions respond to the opportunities and challenges posed by AEL. This suggests a relationship between "policy" and "innovation" that requires a focus on developing regulations that promote and fund innovative approaches to AEL. Higher education institutions must therefore adapt their regulatory and funding systems to meet the demands of this changing paradigm. Terms such as "equity," "personality," "student success," "adaptive support," "optimization," "flexibility," "usability," "adaptability," and "accessibility" have highlighted the need to ensure that higher education students in AEL have positive learning experiences. While terms such as "online learning platforms," "open learning," and "massive open online courses" have drawn attention to the growing trend of flexible and open learning models in higher education. On the other hand, terms such as "learning algorithm," "adaptive control," "adaptive filtering," "adaptive learning rates," and "artificial neural network" have highlighted the impact of AI on AEL to provide students with individualized instruction (Levin & Isakova, 2024).

Therefore, there is a need to leverage policies to help students succeed in adaptive environments and institutional initiatives to promote AI-powered AEL. Additionally, further research could investigate how to better navigate the opportunities and challenges of implementing adaptive learning in different institutional contexts. This would enable educators to model and guide students toward safe and ethical behavior when using AI.

4.6.4. Group 4: Students' perspectives and experiences.

57 keywords were found in the yellow area. The words in this group are focused on the student as a component of AEL. Terms such as "cognition," "motivation," "student satisfaction," "student engagement," "learning preferences," and "attitudes" draw attention to two things: the first is the importance of obtaining student input and understanding the scope of their experiences, and the second is the importance of understanding students' attitudes, interactions, and feelings about adaptive learning environments. While terms such as "reinforcement learning," "adaptive models," "data privacy," "personalized learning," "individualized learning," "learner model," and "self-adaptive systems" indicate a focus on delivering adaptive content tailored to meet the needs of specific students. On the other hand, terms that indicate consideration of the social and emotional aspect in adaptive environments were found: "group model," "collaborative learning," and "community" (Khazgalieva et al., 2023).

While terms such as "autonomy," "independence," and "self-directed learning" emphasize supporting students' autonomy and decision-making abilities. Terms such as "diversity," "enhancement," and "personalization" refer to taking into account the characteristics of all students, regardless of their background or learning preferences. Therefore, it would be useful to conduct further studies on the unique characteristics of student groups in developing adaptive environments. In addition, successful strategies for enhancing student engagement and addressing emotional and social needs would be useful (Chugh et al., 2023).

4.6.5. Cluster 5 Infrastructure of AI and technology

35 keywords were found in the purple area of the map. This group focused on the architecture and technology of AEL. Keywords such as "adaptive management system," "AI technology," "eye movement," "eye tracking," "intelligent adaptive platforms," "automation," and "infrastructure" highlighted the need for comprehensive planning and preparation of technology infrastructure that supports accessibility and goals for higher education. The importance of selecting and using reliable technology tools and platforms. The importance of usability and accessibility through terms such as "availability," "usefulness," "user interface," "design," and "integration."

On the other hand, words such as "engagement," "collaboration," "personalization," "communication," "interaction," and "integration" indicate an interest in inclusive instructional design approaches and usability. The focus is on integrating the use of AI technology to develop dynamic, engaging adaptive environments. Keywords such as "artificial intelligence," "intelligent transportation systems," "adaptive wearable technology," and "intelligent agents" highlight the potential of these technologies to further improve adaptive learning. Terms such as "adaptive multimedia," "adaptive neural networks," "recommender system," and

"intelligent tutoring system". Terms such as "big data," "cloud computing," "data mining," "data analytics," and "learning analytics" indicate the desire to use data-driven methods to enhance and personalize learning to develop adaptive environments. Future studies could investigate best practices for integrating AI technologies into adaptive learning, and address issues related to usability and accessibility in adaptive environments (Gligorea, et al., 2023).

4.6.6. Cluster 6: Designing and Delivering Curricula for AEL

Five keywords are shown on the map in the light blue area. This cluster emphasizes how curricula are delivered and adapted to accommodate personalized learning. The keyword "curricula" emphasizes how important it is to properly organize educational content and learning exercises to support independent and personalized learning. Strategies for independent learning and self-interaction with content are referenced through the terms "personalized content" and "self-learning." Terms such as "AI" and "personalized learning" emphasize several things: 1) the close connection between curricula, self-paced learning, and AI technologies; 2) the integration of emerging AI technologies to provide a platform for delivering adaptive educational information; 3) a focus on developing learning environments that leverage the capabilities of AI technologies, such as intelligent tutoring systems, adaptive multimedia, and recommendation systems; 4) an emphasis on adapting learning methodologies and curricula to suit the unique needs of students; 5) highlighting the centrality of the learner by using qualitative research methods such as interviews, questionnaires, and observations to collect data on students' experiences and learning outcomes in adaptive environments.

The term "adaptive learning" calls for consideration of students' motivation and autonomy in individualized environments. Whereas "self-paced learning" refers to flexible and customizable learning paths. Terms from other groups, such as "MOOCs" and "open learning," refer to the acceptance of online learning materials that are adaptable, readily available, and provide high-quality education at affordable prices (Mohapatra & Mohanty, 2017). To achieve the best learning outcomes in AEL environments, further investigation is needed into how to design and implement self-paced learning approaches that empower learners, promote independent learning, and make the most of the latest web-based technologies(Mejeh et al., 2024).

4.7. Research focus on publication year

The network visualization map in Figure 7 shows the 578 co-occurring keyword groups according to the publication years. The 2018-2019 adaptive learning study found that "adaptive multimedia", "personalized learning" and "intelligent recommendation systems" were included in at least 10 cases. "Intelligent teaching system", "learning algorithm", "machine learning" and "higher education" were researched between 2020 and 2021 in the green area. "AEL environment", "AEL", "eye tracking" and "AI-powered AEL" were the research topics conducted in this area between 2021 and 2022 in the green space.

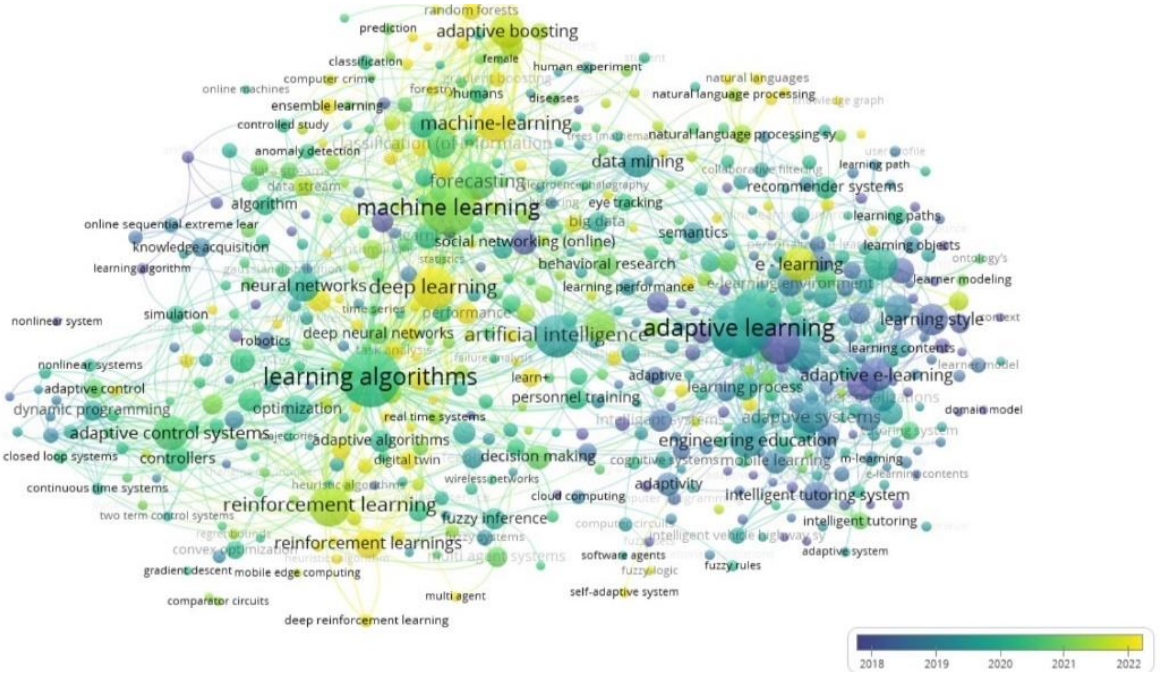

Fig. 7: Map of networks showing co-occurring keywords throughout time

Since AEL is a result of the use of artificial intelligence, it has clearly expanded over the past five years. It is noticeable that even if there are "many" topics of study, the newer keywords are "synonyms" for the more established topics. There is a need to investigate the areas of AEL frameworks, educator competencies required for successful implementation, and accessibility challenges. A comprehensive learner model should be created that takes into account the unique needs of the student. Studies on AI-powered adaptive learning environments and systems should continue (Demartini et al., 2024; Lin et al., 2023).

4.8. Discussion

This research used bibliometric analysis to conduct a systematic review of AEL in the educational literature. In the bibliometric analysis, the keyword co-occurrence analysis reveals four of the concept clusters explored in the literature. The keyword co-occurrence network highlights six concept clusters: Adaptive Learning Technology; Students' perspectives and experiences; Development of educators, governance, policy, and management; Infrastructure of AI and technology; Designing and Delivering Curricula for AEL. In contrast, the author keyword co-occurrence network illustrates the concept clusters of adaptive learning, machine learning, learning algorithms, deep learning, and reinforcement learning. A closer examination reveals the similarities and differences between these two sets of clusters. The clusters derived from the author keywords provide a more detailed perspective than those defined in the keyword network. For example, the adaptive learning, learning algorithms, and machine learning clusters in the author keyword network correspond to the design science cluster in the keyword network.

Although traditional e-learning has provided opportunities for availability and flexibility at any time and place of learning, and provided a single education for all learners; it did not provide education that suits the unique characteristics of learners(El-Sabagh, 2021). Therefore, AEL came to provide education that adapts to the requirements, abilities and characteristics of each student (Mejeh& Rehm, 2024). Here, higher education institutions and educators have realized the benefits of AEL and its positive impact on personalized learning and lifelong learning. AEL bypasses physical limitations, personalizes access to knowledge, and enhances learning environments for learners. AEL is currently being positioned as a game-changer in higher education due to the shift from traditional e-learning to AI-powered AEL(Kamalov et al., 2023). More accessibility, flexibility, personalization, ease of use, and availability are the benefits of AI-powered AEL. In other words, AEL is a powerful pedagogical strategy that is reshaping higher education rather than a temporary solution(Johnson et al., 2023).

The research analysis and conclusions point to a comprehensive strategy that includes infrastructure,

curriculum design, leadership, pedagogy, student experience, and AEL technologies. This highlights the importance of digital pedagogy and the critical role of AI technologies in enabling AEL. To create engaging and interactive learning experiences in higher education. It is necessary to focus on smart platforms, smart tools, smart teaching systems, smart recommendation systems, and adaptive learning management systems. On the other hand, focus on education, student growth, motivation, and engagement. In line with the requirements of modifying and improving teaching strategies and assessment techniques for use in adaptive environments(Ukenova& Bekmanova, 2023). According to research on assessment methodologies, measuring and improving learning outcomes in adaptive environments is problematic. Therefore, they must be redesigned in a way that is different from standard assessments. This underscores the importance of providing teachers with the tools they need to succeed in adaptive situations when it comes to assessment and reinforcement. The need to provide teachers with the skills and information they need to succeed in this changing environment makes professional development programs important (Chi & Oanh, 2023).

Leadership, strategic planning, and policy development are essential for the successful management of AEL. To integrate AEL practices into higher education institutions, it is necessary to reach a transformational rather than a substitutional level(Morze et al., 2021). Therefore, it becomes necessary to design policies that support the discovery of new and effective ways of adaptive learning. This emphasizes the importance of knowing students' perceptions and experiences to improve AEL environments. In addition to meeting academic needs, a more student-centered design of an AEL environment will also take into account students' social and emotional experiences, learning preferences, and learning styles (Tan et al., 2021).

Research trends in AEL have been the focus of this research, and here the broader implications of AEL in higher education need to be considered. Although AEL is less expensive than physical classrooms, investment in infrastructure and support services is required to ensure equitable access for learners with limited use of technology(Sato et al., 2024). Here comes the need for research into sustainable and cost-effective approaches to AEL. Therefore, to facilitate AEL, careful planning, design, development and investment in appropriate technical infrastructure are needed. Future studies should focus on assessing the effectiveness of different strategies, taking into account social, emotional and cultural factors and incorporating digital pedagogy. Research on adaptive e-learning and digitalization in Africa is warranted, given the contextual realities of developing countries (Chugh et al., 2023). In addition to conducting further exploratory studies into the potential uses of AI-powered adaptive learning in educational settings. On the other hand, higher education institutions can use AEL to foster an innovative culture and provide unique educational experiences. In this case, they will be able to shape the future of higher education.

5. CONCLUSION

This research uses bibliometric analysis to uncover and understand the key concepts in the field of AI-based AEL. This study contributes to the literature review on AEL by emphasizing the importance of understanding the conceptual structure of the field. In addition, the research suggests several future directions, including the need to integrate AI technologies, promote AI research in the context of higher education, enhance the quality of research through mixed methods, prioritize theoretical contributions, and enhance collaboration between computer scientists, psychologists, educators, and MIS experts. It draws attention to the need for innovative leadership and laws that ensure equitable access and academic achievement for all students. In addition, the research highlights the importance of understanding and meeting students' learning preferences, requirements, experiences, and learning styles to create motivating adaptive learning systems.

5.1. Theoretical Implications

The student-centered learning perspective and technology-based education suggest a potential shift in adaptive environments towards constructivist and student-centered models. This calls for further study of individual learning trajectories and techniques for engaging students in adaptive environments. However, this places a need for professional development and support for teachers, emphasizing the need to equip teachers with the skills and information required to succeed in this changing paradigm. The focus on policy and governance guidance in adaptive learning further underscores the need for theoretical frameworks and best practices for integrating adaptive learning into the larger infrastructure of higher education. Research into leadership styles, resource allocation, and policy creation that support the implementation of adaptive e-learning models can be part of this.

5.2. Practical Implications

Improving adaptive e-learning experiences requires a complex strategy. By redesigning curricula to take advantage of the capabilities of learning management systems, adding options for personalizing student learning, interactive media, and adaptive exercises. Focusing on digital pedagogy, which relies on artificial intelligence, on designing and developing learning experiences within adaptive platforms. Focusing on preparing teachers for the requirements of adaptive e-learning, which can be achieved by creating and implementing digital professional development programs. The importance of developing communities of practice and supportive peer networks to help teachers deal with this shift in obtaining technological proficiency and teaching techniques. Furthermore, creating equitable, encouraging, and adaptive learning environments requires a comprehensive understanding of students' preferences and experiences. Higher education institutions must therefore provide students with training, support services, and accessible technologies. In addition to technical issues, providing individualized support services to students in adaptive environments is critical. This includes academic coaching, technical assistance, and other tools to ensure students' performance in adaptive learning environments.

5.2. Research Limits and Future Studies

Although there are some limitations to this bibliometric study, overall, it adds to the expanding body of scientific knowledge. The bibliometric review was limited to published literature found in the Scopus database as well as the time period. Future studies could benefit from published literature from other databases and periods. The current bibliometric analysis was limited to conference papers and articles published in English in the fields of computer science, social sciences, arts and humanities. Future studies could expand its scope to include diverse cultural environments and educational frameworks. In addition, the topic of adaptive e-learning is rapidly evolving and advancing. Therefore, future studies should include emerging technologies and explore their potential impact on adaptive learning models. Future studies should investigate ways to adopt and expand adaptive e-learning programs. Studies to examine the potential of AI and adaptive e-learning technologies to enhance student engagement and personalize learning experiences.

REFERENCES

Ahmed, A., Ibrahim, A. (2023). The Effectiveness of Adaptive Learning Methods in Mathematics Compared to Flipped Learning analyzed by ANN and IoT. Wireless Pers Commun https://doi.org/10.1007/s11277-023-10500-6

Ajeel, N. (2022). The advantages and disadvantages of electronic learning from the point of view of the technical trainees institute during the covid-19 pandemic. RIMAK International journal of humanities and social sciences, 4(2). 42-55. Doi: 10.47832/2717-8293.16.4

Alakabawy, B. (2024). Artificial intelligence in the educational stages from kindergarten to university: A systematic review of Arab studies from 2010 to 2023. E-Learning and Digital Media, 0(0). https://doi.org/10.1177/20427530241276140

Alenezi, M., Wardat, S., & Akour, M. (2023). The Need of Integrating Digital Education in Higher Education: Challenges and Opportunities. Sustainability, 15(6), 4782. https://doi.org/10.3390/su15064782

Amobonye, A., Lalung, J., Mheta, G., & Pillai, S. (2024). Writing a Scientific Review Article: Comprehensive Insights for Beginners. The Scientific World Journal, 7822269. https://doi.org/10.1155/2024/7822269

Atef, M., Gamalel-Din, S., & Tharwat, G. (2022). adaptive learning environments based on intelligent manipulation for video learning objects. Journal of Al-Azhar University Engineering Sector, 17(62), 312-323. doi: 10.21608/auej.2022.216816

Bhaiswar, R., Meenakshi, N., & Chawla, D. (2021). Evolution of Electronic Word of Mouth: A Systematic Literature Review Using Bibliometric Analysis of 20 Years (2000–2020). FIIB Business Review, 10(3), 215-231. https://doi.org/10.1177/23197145211032408

Bower, M., Torrington, J., Lai, M. et al.(2024). How should we change teaching and assessment in response to increasingly powerful generative Artificial Intelligence? Outcomes of the ChatGPT teacher survey. Educ Inf Technol, 29, 15403–15439. https://doi.org/10.1007/s10639-023-12405-0

Carchiolo, V., Grassia, M., Malgeri, M., & Mangioni, G. (2022). Co-Authorship Networks Analysis to Discover Collaboration Patterns among Italian Researchers. Future Internet, 14(6), 187. https://doi.org/10.3390/fi14060187

Chalkiadakis, A., Seremetaki, A., Kanellou, A., Kallishi, M., Morfopoulou, A., Moraitaki, M., & Mastrokoukou,

S. (2024). Impact of Artificial Intelligence and Virtual Reality on Educational Inclusion: A Systematic Review of Technologies Supporting Students with Disabilities. Education Sciences, 14(11), 1223. https://doi.org/10.3390/educsci14111223

Chen, H., Law, V. & Huang, K. (2023). Adaptive scaffolding and engagement in digital game-based learning. Education Tech Research Dev. 71, 1785–1798. https://doi.org/10.1007/s11423-023-10244-x

Chi, P., & Oanh, K. (2023). Proposing a process for training online teaching competence for lecturers at higher education institutions. Journal of Education and e-Learning Research, 10(3), 502–512. https://doi.org/10.20448/jeelr.v10i3.4893

Christodoulou. A.,& Angeli, C. (2022). Adaptive Learning Techniques for a Personalized Educational Software in Developing Teachers' Technological Pedagogical Content Knowledge. Front. Educ. 7.789397. doi: 10.3389/feduc.2022.789397

Chugh, M., Vyas, S., Shukla, K. (2023). Adaptive Gamification in E-Learning Platforms: Enhancing Learners' Experience. In: Singh, Y., Verma, C., Zoltán, I., Chhabra, J.K., Singh, P.K. (eds) Proceedings of International Conference on Recent Innovations in Computing. ICRIC 2022. Lecture Notes in Electrical Engineering, vol 1011. Springer, Singapore. https://doi.org/10.1007/978-981-99-0601-7_48

Chughtai, S., Syed, F., Naseer, S. et al.(2024) Role of adaptive leadership in learning organizations to boost organizational innovations with change self-efficacy. Curr Psychol, 43, 27262–27281. https://doi.org/10.1007/s12144-023-04669-z

Demartini, G., Sciascia, L., Bosso, A., & Manuri, F. (2024). Artificial Intelligence Bringing Improvements to Adaptive Learning in Education: A Case Study. Sustainability, 16(3), 1347. https://doi.org/10.3390/su16031347

Elmaadaway, N.,& Abouelenein, M. (2023). In-service teachers' TPACK development through an adaptive e-learning environment. Educ Inf Technol 28, 8273–8298 https://doi.org/10.1007/s10639-022-11477-8

El-Sabagh, A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. Int J Educ Technol High Educ 18, 53. https://doi.org/10.1186/s41239-021-00289-4

Ezzaim, A., Dahbi, A., Haidine, A.,& Aqqal, A.(2023) . AI-Based Adaptive Learning: A Systematic Mapping of the Literature. Journal of Universal Computer Science, 29(29). 1161-1197. DOI:10.3897/jucs.90528

Fadieieva, L. (2023). Bibliometric Analysis of Adaptive Learning Literature from 2011-2019: Identifying Primary Concepts and Keyword Clusters. In: Antoniou, G., et al. Information and Communication Technologies in Education, Research, and Industrial Applications. ICTERI 2023. Communications in Computer and Information Science, vol 1980. Springer, Cham. https://doi.org/10.1007/978-3-031-48325-7_16

Gligorea, I., Cioca, M., Oancea, et al. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. Education Sciences, 13(12),1216. https://doi.org/10.3390/educsci13121216

Güngören, C., Gür Erdoğan, D., Çelik, N., Bilgin, S., & Köse, K. (2024). The trends in adaptive learning research: A bibliometric analysis study. International Journal of Educational Research Review, 9(3), 160-183. DOI: 10.24331/ijere.1438344

Hallinger, P., & Nguyen, T. (2020). Mapping the landscape and structure of research on education for sustainable development: A bibliometric review. In Sustainability (Switzerland) 12 (5). 1947. https://doi.org/10.3390/su12051947

Ilić, M., Mikić, V., Kopanja, L.,& Boban, V.(2023). Intelligent techniques in e-learning: a literature review. Artif Intell Rev, 56, 14907–14953. https://doi.org/10.1007/s10462-023-10508-1

Iyer, P.,& Debang, M. (2023). The Future of Adaptive E-Learning: Trends and Directions. doi: 10.31235/osf.io/xs78z

Johnson, C., Walton, B., Strickler, L., & Elliott, B. (2023). Online Teaching in K-12 Education in the United States: A Systematic Review. Review of Educational Research, 93(3), 353-411. https://doi.org/10.3102/00346543221105550

Jose, J., Joseph, A., , Abraham, P., , Varghese, R. , Beenamole, T. , Varghese, S.,& Oommen, S. (2024). Transformative Pedagogies: A Bibliometric Journey Through Adaptive Learning Systems. Journal of Theoretical and Applied Information Technology, 102 (6). https://www.jatit.org/volumes/hundredtwo6.php

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. Sustainability, 15(16), 12451. https://doi.org/10.3390/su151612451

Koutsantonis, D., Koutsantonis, K., Bakas, P., Plevris, V., Langousis, A., & Chatzichristofis, A. (2022). Bibliometric Literature Review of Adaptive Learning Systems. Sustainability, 14(19), 12684. https://doi.org/10.3390/su141912684

Krechetov, I., & Romanenko, V. (2020). Implementing the Adaptive Learning Techniques. Voprosy Obrazovaniya / Educational Studies Moscow, (2), 252-277. https://doi.org/10.17323/1814-9545-2020-2-252-277

Kurniawan, C.,& Kusumaningrum, S. (2021). Analysis of Trends in Adaptive Learning Using Google Trends and Bibliometric. International Conference on Information Technology and Education (ICITE). DOI:10.2991/assehr.k.211210.015

Levin., M.,& Isakova, I. (2024). Adaptive Education as a Key Element for Enhancing the Effectiveness of Learning Processes. Cifrovaâ transformaciâ, 30(2), 5-10. https://doi.org/10.35596/1729-7648-2024-30-2-5-10

Lin, C., Huang, Q. & Lu, T.(2023). Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. Smart Learn. Environ. 10(41). https://doi.org/10.1186/s40561-023-00260-y

Linnenluecke, K., Marrone, M., & Singh, K. (2020). Conducting systematic literature reviews and bibliometric analyses. Australian Journal of Management, 45(2), 175-194. https://doi.org/10.1177/0312896219877678

Makda, F. (2024). Digital education: Mapping the landscape of virtual teaching in higher education – a bibliometric review. Educ Inf Technol. https://doi.org/10.1007/s10639-024-12899-2

Marín-Vinuesa, M., & Rojas-García, P. (2024). Expected Usefulness of Interactive Learning Platforms and Academic Sustainability Performance: The Moderator Role of Student Enjoyment. Sustainability, 16(9), 3630. https://doi.org/10.3390/su16093630

Mejeh, M.,& Rehm, M.(2024). Taking adaptive learning in educational settings to the next level: leveraging natural language processing for improved personalization. Education Tech Research Dev, 72, 1597–1621. https://doi.org/10.1007/s11423-024-10345-1

Mohapatra, S., & Mohanty, R. (2017). Adopting MOOCs for affordable quality education. Education and Information Technologies, 22(5), 2027–2053. https://doi.org/10.1007/s10639-016-9526-5

Morze, N., Varchenko-Trotsenko, L., Terletska, T.,& Smyrnova-Trybulska, E. (2021). Implementation of adaptive learning at higher education institutions by means of Moodle LMS. Journal of Physics Conference Series, 1840(1),012062. DOI:10.1088/1742-6596/1840/1/012062

Narong, K., & Hallinger, P. (2023). A Keyword Co-Occurrence Analysis of Research on Service Learning: Conceptual Foci and Emerging Research Trends. Education Sciences, 13(4), 339. https://doi.org/10.3390/educsci13040339

Öztürk, O., Kocaman, R. & Kanbach, K.(2024). How to design bibliometric research: an overview and a framework proposal. Rev Manag Sci, 18, 3333–3361. https://doi.org/10.1007/s11846-024-00738-0

Passas, I. (2024). Bibliometric Analysis: The Main Steps. Encyclopedia, 4(2), 1014-1025. https://doi.org/10.3390/encyclopedia4020065

Peng, H., Ma, S. & Spector, M.(2019). Personalized adaptive learning: an emerging pedagogical approach enabled by a smart learning environment. Smart Learn. Environ, 6(9). https://doi.org/10.1186/s40561-019-0089-y

Pera, S., Cena, F., Landoni, M., Musto, C.,& Starke, D. (2024). Human Factors in User Modeling for Intelligent Systems. In: Ferwerda, B., Graus, M., Germanakos, P., Tkalčič, M. (eds) A Human-Centered Perspective of Intelligent Personalized Environments and Systems. Human–Computer Interaction Series. Springer, Cham. https://doi.org/10.1007/978-3-031-55109-3_1

Phan, T., Vu, T., Doan, T., Luong, H., Bui, P., Le, H., & Nguyen, H. (2022). Two decades of studies on learning management system in higher education: A bibliometric analysis with Scopus database 2000–2020. Journal of University Teaching & Learning Practice, 19(3), 09. DOI: 10.53761/1.19.3.09

Qu, Y.,& Ogunkunle, O.(2021). Enhancing the Intelligence of the Adaptive Learning Software through an AI assisted Data Analytics on Students Learning Attributes with Unequal Weight. IEEE Frontiers in Education Conference (FIE), Lincoln, NE, USA. 1-6, doi: 10.1109/FIE49875.2021.9637387

Rincon-Flores, G., Castano, L., Guerrero Solis, L., Lopez, O., Hernández, C., Lara, L.,& Valdés, L. (2024). Improving the learning-teaching process through adaptive learning strategy. Smart Learn. Environ. 11(27). https://doi.org/10.1186/s40561-024-00314-9

Roddy, C., Amiet, L., Chung, J., Holt, C., Shaw, L., McKenzie, S., Garivaldis, F., Lodge, M., & Mundy, E. (2017). Applying Best Practice Online Learning, Teaching, and Support to Intensive Online Environments: An Integrative Review. Front. Educ. 2(59). doi: 10.3389/feduc.2017.00059

Sanders, K., & Scanlon, E. (2021). The Digital Divide Is a Human Rights Issue: Advancing Social Inclusion Through Social Work Advocacy. Journal of human rights and social work, 6(2), 130–143. https://doi.org/10.1007/s41134-020-00147-9

Sato, N., Condes Moreno, E., Rubio-Zarapuz, A., Dalamitros, A., Yañez-Sepulveda, R., Tornero-Aguilera, F., & Clemente-Suárez, J. (2024). Navigating the New Normal: Adapting Online and Distance Learning in the Post-Pandemic Era. Education Sciences, 14(1), 19. https://doi.org/10.3390/educsci14010019

Suh, K., Hand, B., Ercan-Dursun, J., Sahin, E., & Fulmer, G. (2024). Exploring the Complexity of Adaptive Teaching Expertise within Knowledge Generation Environments. Education Sciences, 14(4), 415. https://doi.org/10.3390/educsci14040415

Sweileh, M. (2021). Global Research Activity on E-Learning in Health Sciences Education: a Bibliometric Analysis. Medical science educator, 31(2), 765–775. https://doi.org/10.1007/s40670-021-01254-6

Szymkowiak, A., Melović, B., Dabić, M., Jeganathan, K., & Kundi, S. (2021). Information technology and Gen Z: The role of teachers, the internet, and technology in the education of young people. Technology in Society, 65, 101565. https://doi.org/10.1016/j.techsoc.2021.101565

Tandon, A., Kaur, P., Mäntymäki, M., & Dhir, A. (2021). Blockchain applications in management: A bibliometric analysis and literature review. Technological Forecasting and Social Change, 166, 120649. https://doi.org/10.1016/j.techfore.2021.120649

Taylor, L., Yeung, M., Bashet, Z. (2021). Personalized and Adaptive Learning. In: Ryoo, J., Winkelmann, K. (eds) Innovative Learning Environments in STEM Higher Education. SpringerBriefs in Statistics. Springer, Cham. https://doi.org/10.1007/978-3-030-58948-6_2

Truong, M. (2016). Integrating learning styles and AEL system: Current developments, problems and opportunities. Comput. Hum. Behav., 55, 1185-1193. https://doi.org/10.1016/j.chb.2015.02.014

Ukenova, A. & Bekmanova, G. (2023). A review of intelligent interactive learning methods. Front. Comput. Sci, 5,1141649. doi: 10.3389/fcomp.2023.1141649

Wang, J. (2024). Impact of natural disasters on student enrollment in higher education programs: A systematic review. Heliyon, 10(6), e27705. https://doi.org/10.1016/j.heliyon.2024.e27705

Wijaya, A., Setiawan, N.,& Shapiai, M.(2023). Mapping Research Themes and Future Directions in Learning Style Detection Research: A Bibliometric and Content Analysis. The Electronic Journal of e-Learning, 21(4):274-285. DOI:10.34190/ejel.21.4.3097

Yu, L., Muhammad R., Sharifah Z., Lee E., Amir H.,& Vinay C.(2024). Utilizing ubiquitous learning to foster sustainable development in rural areas: Insights from 6G technology. Computers in Human Behavior, 161. https://doi.org/10.1016/j.chb.2024.108418