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The Future of Distance Education: Exploring the Potential of Adaptive Learning Systems

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Abstract

Adaptive learning technologies are used in many areas of education, including online distance learning. This study investigates the applications of Adaptive Learning technology in distance education environments. Following the steps of systematic literature review and using bibliometric analysis, the study examines a total of 1071 publications. Accordingly, time trend analysis has increased steadily within recent years, and Educational Research, Computer Science, and Engineering are the leading subject areas in research on Adaptive Learning in distance education. China and USA are the countries that make the most of the contribution, followed by Taiwan, Spain, and India. Kinshuk is the author who contributed the most, followed by Caballé and Santi. The most collaborative authors are Capuano and Nicola, Ritrovato and Pierluigi, Cabelle and Santi, and Gaeta and Matteo. Pierri and Anna hold central positions in the co-authoring network. The top three journals with the most publications are Computers & Education, International Journal of Distance Education, and Academic Medicine, all with significant citation counts. The most frequently used keywords are “e-learning”, followed by “adaptive learning”, and “online learning”. Integrating artificial intelligence and machine learning techniques presents significant potential for enhancing adaptive learning technologies. Utilizing frameworks such as learning analytics and the Technology Acceptance Model can help identify effective strategies to increase system acceptability.

Keywords: adaptive learning, distance education, systematic literature review, bibliometric analysis

Uzaktan Eğitimin Geleceği: Uyarlanabilir Öğrenme Sistemlerinin Potansiyelini Keşfetmek

Öz

Uyarlanabilir öğrenme teknolojileri, çevrim içi uzaktan eğitim de dahil olmak üzere birçok eğitim alanında kullanılmaktadır. Bu çalışma, uyarlanabilir öğrenme teknolojisinin uzaktan eğitim ortamlarındaki uygulamalarını araştırmaktadır. Sistematik literatür taraması adımlarını izleyerek ve bibliyometrik analiz kullanarak, çalışma toplamda 1071 yayını incelemektedir. Buna göre, son yıllarda zaman eğilimi analizi istikrarlı bir artış göstermiş olup, uzaktan eğitimde uyarlanabilir öğrenme üzerine yapılan araştırmalarda Eğitim Araştırmaları, Bilgisayar Bilimleri ve Mühendislik önde gelen konu alanlarıdır. Çin ve ABD en fazla katkıda bulunan ülkeler olup, onları Tayvan, İspanya ve Hindistan takip etmektedir. En çok katkıda bulunan yazar Kinshuk iken, onu Caballé ve Santi izlemektedir. En çok iş birliği yapan yazarlar Capuano ve Nicola, Ritrovato ve Pierluigi, Caballé ve Santi ile Gaeta ve Matteo'dur. Pierri ve Anna, ortak yazar ağında merkezi konumlara sahiptir. En fazla yayına sahip ilk üç dergi, önemli atıf sayılarıyla Computers & Education, International Journal of Distance Education ve Academic Medicine'dir. En sık kullanılan anahtar kelimeler “e-öğrenme”, ardından “uyarlanabilir öğrenme” ve “çevrimiçi öğrenme”dir. Yapay zekâ ve makine öğrenimi tekniklerinin entegrasyonu, uyarlanabilir öğrenme teknolojilerini geliştirme potansiyelini önemli ölçüde artırmaktadır. Öğrenme analitikleri ve Teknoloji Kabul Modeli gibi çerçevelerin kullanılması, sistemin kabul edilebilirliğini artıracak etkili stratejilerin belirlenmesine yardımcı olabilir.

Anahtar Kelimeler: uyarlanabilir öğrenme, uzaktan eğitim, sistematik literatür incelemesi, bibliyometrik analiz

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Introduction

Distance education and adaptive learning, which are of great importance in education nowadays, are rapidly becoming widespread with the innovations provided by technology. Distance education eliminates equalization by enabling students to access education without geographical restrictions. Especially during the pandemic period, the importance and applicability of distance education have become even more evident. On the other hand, in recent years, the concept of adaptive learning has taken a significant interest in education (Morze et al., 2021). This innovative approach was widely accepted in educational research as a promising alternative to traditional teaching methods (Gligorea et al., 2023). When combined, these two innovative educational approaches enhance quality and accessibility in education, formative the future models of education. However, given the rapid spread of technology and the impact of the digital age, the field of education has various challenges, particularly in the context of distance education (Miralrio et al., 2024). As educators and students deal with the challenges of distance learning, it's important to find new methods to improve teaching and the learning experience (Mezin et al., 2022). Distance education environments, especially when their structure fails to accommodate diverse student models and personalized learning needs, can lead to interaction and communication challenges. This often results in a negative perception of distance education among learners (Kandemir & Kılıç Çakmak, 2024). This situation, combined with the accessibility to big data sources and the widespread adoption of learning analytics, raises the question of how the adaptive learning approach can be used more effectively in distance education. At this stage, artificial intelligence technologies are introduced into the process.

Artificial intelligence (AI) technologies can play an important role in enhancing various aspects of online learning and teaching in higher education. It can help identify and predict student behaviour and also provide adaptive and personalised learning experiences (Doğan et al., 2023). The use of AI technologies has significant potential to improve learning processes in distance education. The basis of adaptive learning is to respond more effectively to the needs of individual learners and to personalise the learning experience at a detailed level. This makes adaptive learning a useful option for both teachers and students (Muñoz et al., 2022). Furthermore, it is highlighted that AI technologies offer a valuable future for adaptive learning and machine learning has been effectively used to provide personalised educational experiences (Adnan et al., 2021; Srisa-An & Yongsiriwit, 2019). Adaptive learning is becoming an important tool to improve the educational process, especially in distance education where personalisation and adaptability are crucial for a successful learning experience (Kerimbayev et al., 2023). Recent research shows that the adaptive learning approach has significant potential in the education sector (Hakimi et al., 2024; Wang et al., 2023). By harnessing the power of big data analytics, educators can improve student progress and tailor learning materials, leading to a more effective and personalised distance learning experience (da Silva et al., 2021).

Therefore, research in adaptive learning areas is important in terms of determining the best practices in distance education, improving students' learning experiences, and formative future distance education practices. Resources such as the Web of Science are essential for the review and analysis of such studies and provide valuable guidance to future researchers. In the context of contemporary developments in adaptive learning technologies, the primary purpose of this article is to provide a comprehensive review of research on the integration of adaptive learning into the field of distance education. Bibliometric data analysis methods were used to achieve this goal. This study is part of a significant conversion in education and provides an important lead to researchers investigating methods to make learning processes more effective and personalized. In addition, it will lead to researchers who will conduct new studies in the context of distance education regarding the trends in the field.

Method

Research Design

This study used on bibliometric analysis to systematically review and investigate the utilization of adaptive learning technologies in online distance education. The research was conducted through a systematic literature review to identify, select, evaluate, collect, and analyze relevant literature (Moher et al., 2009). The general process steps for a literature review, as illustrated in Figure 1, followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart structure (Moher et al., 2010).

Inclusion Criteria and Sample

The peer-reviewed articles in the literature review fulfill the following criteria:

- Searches were conducted across all fields (Table 1).
- Indexed by Web of Science.
- Written in English.

Conducting searches across all fields aims to provide a thorough understanding of the research and identify peer-reviewed publications that align with the study's overall purpose.

Web of Science is utilized for the following reasons:

Comprehensive Database: Web of Science covers a wide array of scientific disciplines, enabling researchers to access crucial scientific publications across various fields.

Citation Tracking and Analysis: Web of Science offers citation information, showing how frequently a publication is referenced in other works. This aspect is valuable for gauging the impact and importance of research. Citation analysis assists researchers in assessing the impact of their work and spotting research trends.

Standardized Data: Data in Web of Science is presented in a standardized manner, allowing researchers to easily compare and analyze data from diverse studies.

Reliability: Web of Science prioritizes high-quality and dependable scientific publications, establishing it as a reputable resource for researchers.

Bibliometric analysis involves evaluating the quantitative and qualitative characteristics of scientific publications. Web of Science serves as a strong tool for such analyses due to its expansive database, citation-tracking capabilities, standardized data presentation, and reliability. Researchers can build a solid foundation by leveraging these features. Additionally, analyzing English-language publications allows for valid and reliable visual analyses, as text mining benefits from a consistent language for determining lexical relationships in textual data.

Table 1. Information on the Research Corpus and Search Queries Adopted for the Inclusion Criteria

Research Corpus	
Database	Web of Science
Period	2003-2023
Search Queries	
Subject-Specific Queries	"adaptive learning" OR "personalized learning" OR "adaptive educational hypermedia" OR "adaptive educational systems" OR "adaptive e-learning" (All Fields)
Boolean Search Parameter	And
Field-Specific Queries	"distance education" OR "distance teaching" OR "distance learning" OR "remote education" OR "remote learning" OR "remote teaching" OR "online education" OR "online learning" OR "online teaching" OR "online course" OR "elearning" OR "e-learning" OR "m-learning" (All Fields) and 2003 or 2004 or 2005 or 2006 or 2007 or 2008 or 2009 or 2010 or 2011 or 2012 or 2013 or 2014 or 2015 or 2016 or 2017 or 2018 or 2019 or 2020 or 2021 or 2022 or 2023 (Publication Years) and English (Languages) and Article (Document Types)

Figure 1 illustrates the sequential steps of a literature review process. These steps were conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart structure as outlined by (Moher et al., 2010), and the final phase included 1071 publications.

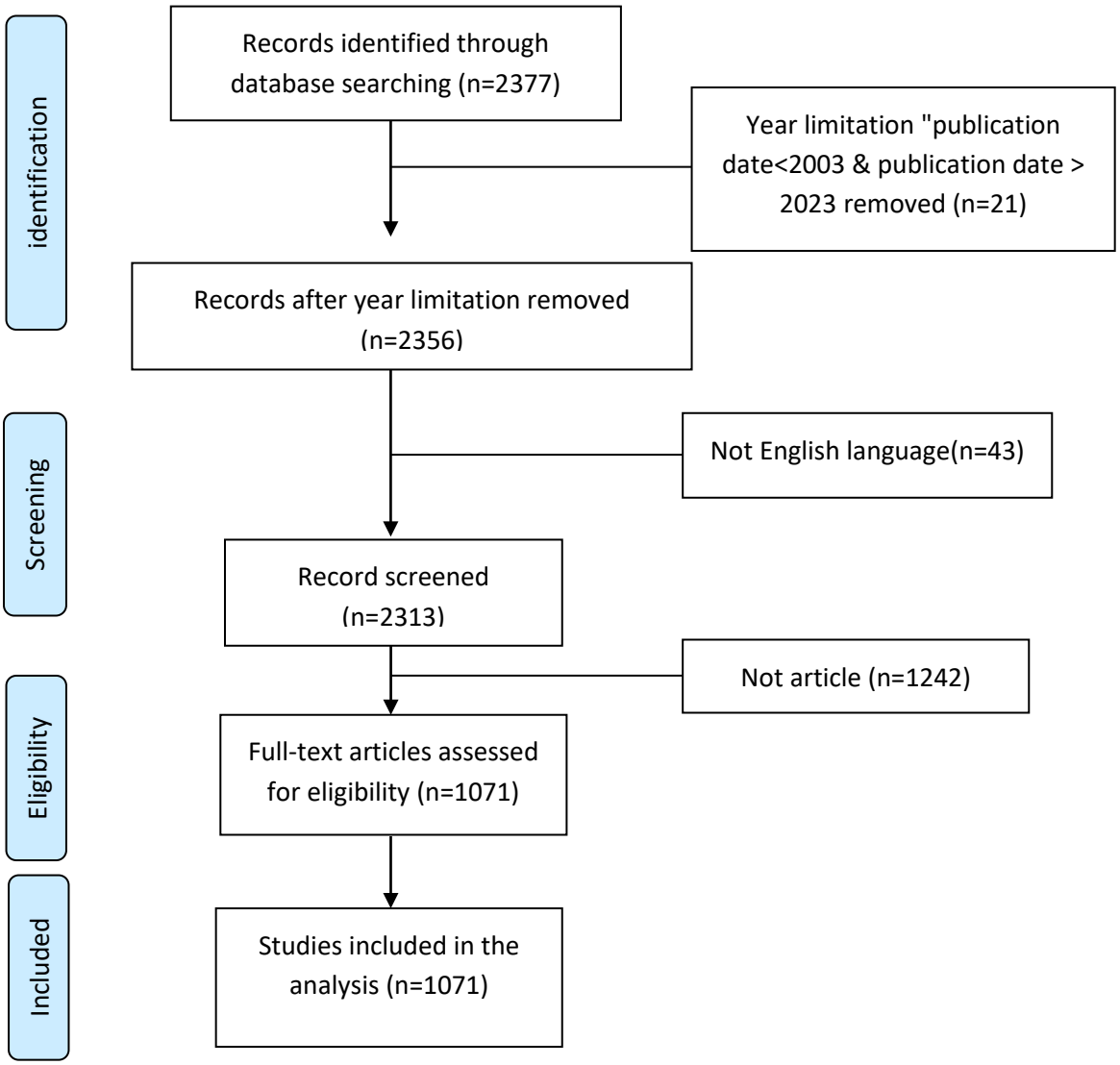

Figure 1. PRISMA Flow Chart for Sourcing

Data Analysis and Research Procedures

In conducting this review, a systematic approach was used to compile the scientific literature. Central to this process was the use of bibliometric factor analysis, a method known for its reliability in identifying common themes in academic research. Relevant articles were collected and reviewed through careful application of bibliometric methods, thus ensuring alignment with the primary objectives of the study.

Strengths and Limitations

The significant strengths of this study lie in its utilization of innovative analytical methods leveraging the capabilities of Web of Science to effectively analyze a substantial volume of textual data and visualize the results. However, the study also acknowledges certain limitations. Firstly, although Web of Science is comprehensive, it may not encompass all publications relevant to the research topic. Therefore, the researchers are aware that the findings of this study may offer a partial perspective. Secondly, due to technical constraints, only English-language publications were included in the final research dataset; however, publications in other languages may contain valuable information. Thirdly, the absence of other analysis methods such as data mining and t-SNE analysis in the study could be considered a limitation. Nevertheless, the absence of these methods did not diminish the value of the study's primary findings, and the results provide valuable insights. Therefore, these limitations should be considered when interpreting the findings.

Findings and Discussions

Time Trend of Adaptive Learning in Online Distance Education Publications

Within the scope of this study, the authors determined the period of the last 20 years. The reason for this is that the number of publications produced before 2003 (n=7) was very small. Accordingly, the research includes publications covering the period between 2003 and 2023. A total of 1071 publications and a total of 3017 authors contributed to the adaptive learning literature in online distance education studies. The distribution of publications by years is given in Figure 2.

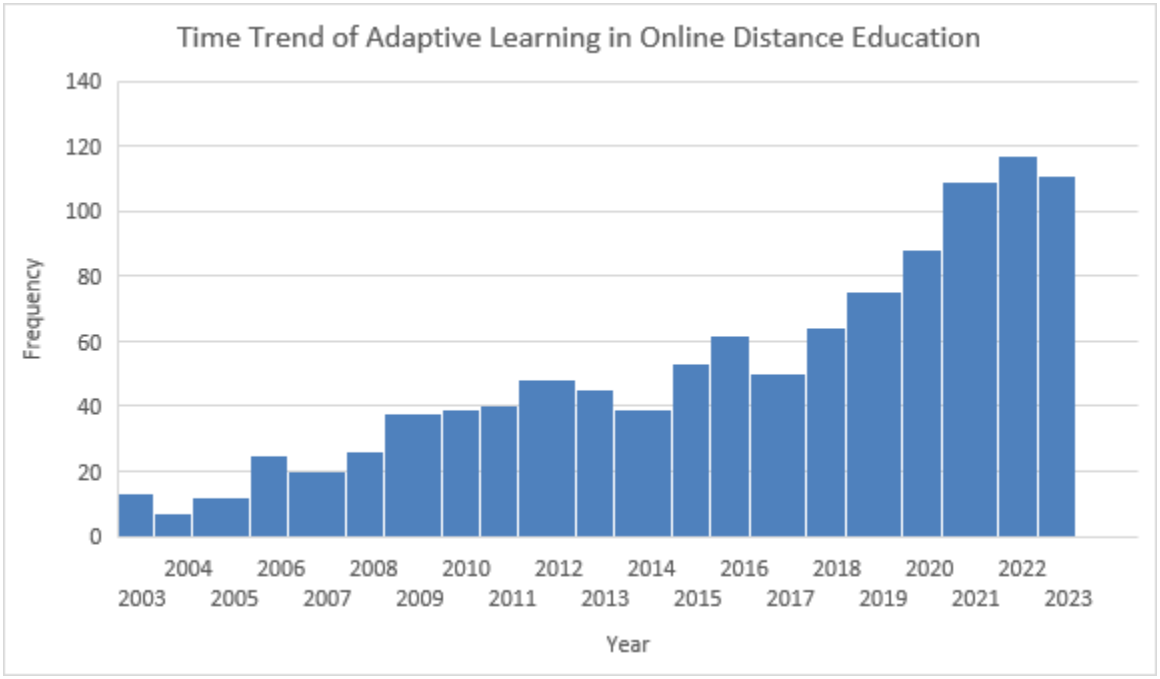

Figure 2. Time Trend of Adaptive Learning in Online Distance Education Publications

As shown in Figure 2, although studies on adaptive learning environments in online distance education date back to the early 2000s, interest began to increase in the second decade of the 2000s; It increased significantly in 2020 and the most work was done in 2022. As seen in Figure 2, the most publications took place in 2022 (n=117). This was followed by 2021 (n=109), 2023 (n=98) and 2020 (n=88), respectively. The fewest publications were recorded in 2004 (n=7).

In a study analyzing research conducted in the field of education within the context of adaptive learning, similar results have emerged. Although the number of publications has varied over the years, an increasing trend has been observed (Martin et al., 2020) Considering Figure 6, it can be noted that the ten-year development plans published by countries such as China, which emphasize the necessity of creating a knowledge-based environment to provide personalized learning services for every student, have been influential in the increase in the number of publications (Li et al., 2021). Additionally, according to the NMC Horizon Report (Higher Education Edition), adaptive learning is expected to make significant advances in higher education. This indicates that adaptive learning has become a major recommendation and a new teaching paradigm for improving education in many countries (Xie et al., 2019), and research on adaptive learning has become a crucial topic in education.

Subject Areas of the Articles on Adaptive Learning in Distance Education

When all articles were examined, it was observed that there were 56 different disciplines. Of these, 17 are represented by only one publication. The disciplines with the highest number of publications are illustrated in Figure 3.

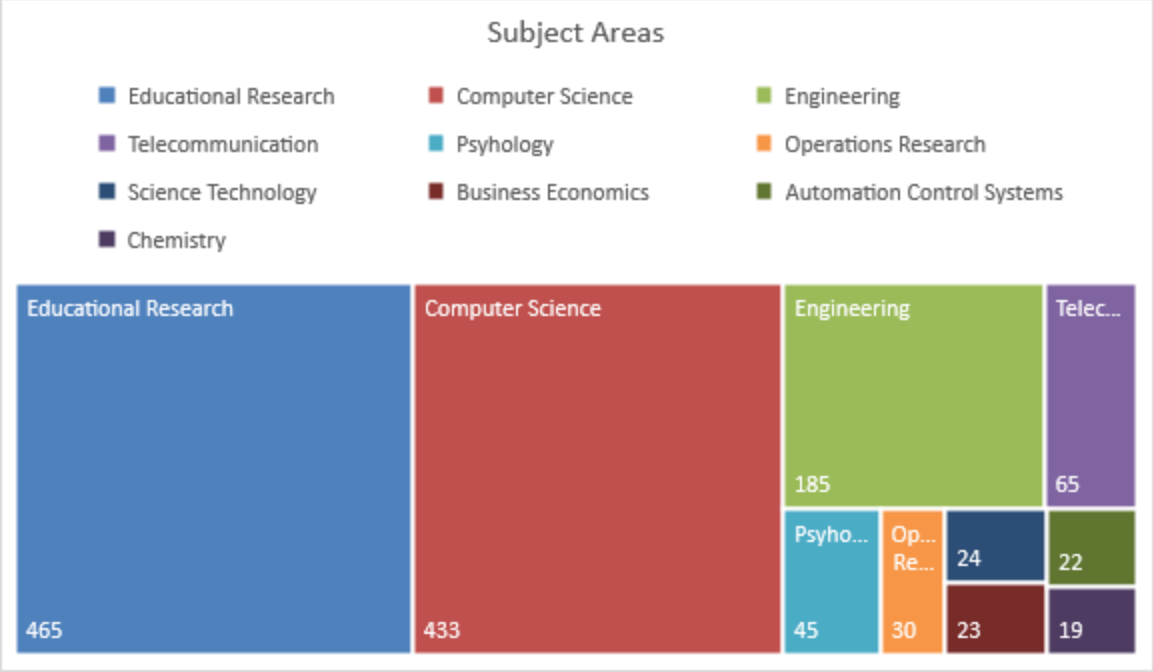

Figure 3. Subject Areas of The Articles on Adaptive Learning in Distance Education

Note. one article can be coded for more than one subject area

From a disciplinary perspective, the top three subject areas accounted for most research (see Figure 3). Educational research dominates other research fields. This is followed by computer science and engineering. Adaptive learning is a fundamental research topic for both computer science and educational technology disciplines and is also an important area where new technologies can improve education and training (Jing et al., 2023). On the other hand, despite the abundance of studies conducted in the field of education, it is seen that computer science and engineering

dominate in some studies (Dogan et al., 2023). However, this does not reflect all the studies. Surprisingly, only 17.27% of studies fall into the field of engineering. This finding shows that most articles prioritize educational pedagogy over technical dimensions. However, it is known that the technical dimension and technology also optimize learning paths, increase participation, and improve academic performance in terms of educational pedagogy (Gligorea et al., 2023). For this reason, it is thought to be important to consider it as an integral part of education.

Distribution of Author Contributions

An analysis was conducted on authors with at least 5 publications and 5 citations. Figure 4 illustrates the distribution of these authors along with the number of their publications.

Figure 4. Distribution of Contributions by Various Authors in the Field

Kinshuk has made significant contributions to this field with 14 publications, and if further research is to be done, his publications should also be looked at. Caballé, Santi, became the second most published author with 8 publications, followed by Capuano, Chen, Essalmi, Graf, Jemni and Tseng each with 7 publications. Other authors Klasnja-Milicevic, Ivanovich, Daradoumis, Chang and Van Der Maas have also made valuable contributions to the field with 6 publications each. The predominance of Chinese authors may be attributed to the vision of the Chinese Ministry of Education in designing instructional environments based on personalized learning services (Li et al., 2021; Li et al., 2022). Chinese researchers are followed by Spanish and Italian researchers because it is noted that the education ministries of these countries fund (García-Tudela et al., 2023) and support new technologies such as adaptive learning environments (Demartini et al., 2024).

Topics with the Highest Citation Counts

Citation topics micro subject areas were examined. This level was preferred because it covers more specific subject areas. There are a totally of 2444 different micro-topics at this level under Web of Science. Small subsets representing the most cited and influential works on the research topic were investigated. Such classification can assist researchers in finding the most current and impactful studies on a specific topic or subfield.

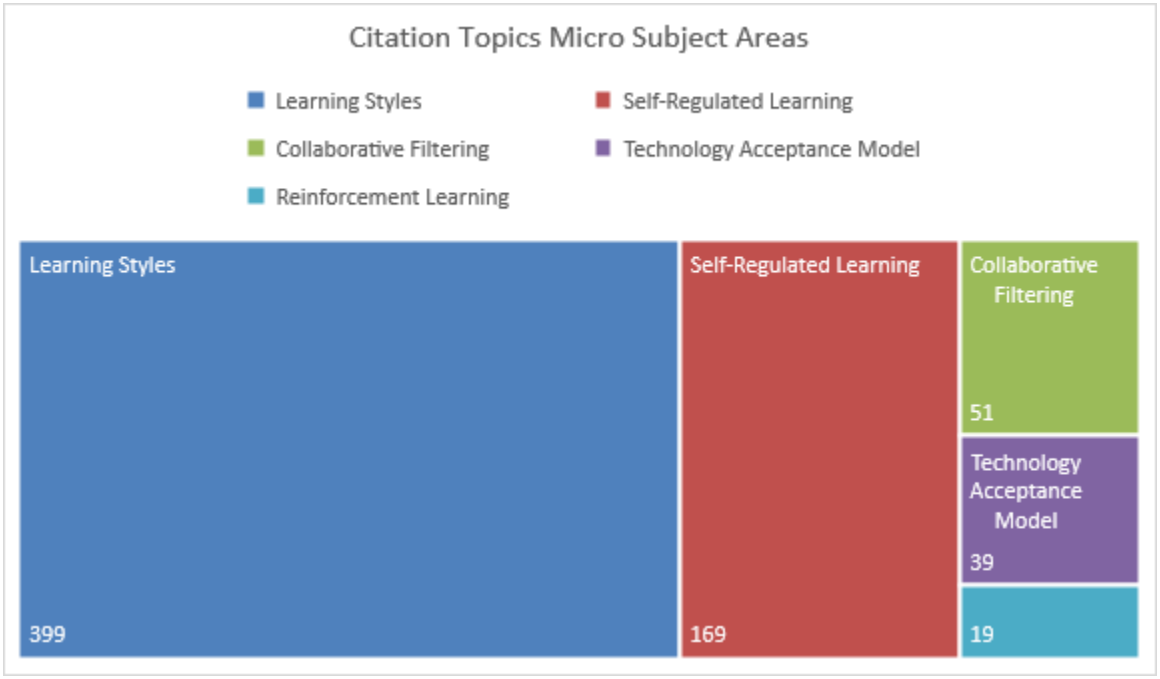

Figure 5. Citation Topics Micro Subject Areas

Upon examination of Figure 5, it is evident that the most studied topic is "Learning Styles" (n=399), followed by "Self-regulated Learning" (n=169). Other topics with a significant number of studies include "Collaborative Filtering" (n=51), "Technology Acceptance Model" (n=39), and "Reinforcement Learning" (n=19), all of which are among the top five most studied secondary topics. The utilization of personalized adaptive learning systems has proven effective in overcoming the limitations of statically determined learning styles (Essa et al., 2023). One reason for the intensive study of this topic could be that adaptive learning systems provide effective means of exploring individuals' learning styles (Haug et al., 2023). Adaptive learning can introduce greater flexibility for students to apply self-regulated learning and assist them in developing responsibility for utilizing opportunities presented in learning environments (Park et al., 2023; van Alten et al., 2020). Therefore, the abundance of research conducted on this topic is remarkable. In addition, it has been stated that utilizing machine learning together with artificial intelligence through educational data mining and learning analytics has brought success in the design of personalized adaptive learning environments in online learning (Garrido & Onaindia, 2013; Lin et al., 2013). It can be stated that these technologies are another factor why learning styles are the most studied area. In this way, content that suits students' learning styles can be designed. Artificial intelligence strengthens educational data mining and learning analytics approaches and facilitates the design of personalized/adaptive learning environments (Dogan et al., 2023).

Countries with the Highest Number of Articles

Research has been conducted in 86 different countries related to the field. The top 10 countries with the most Articles related to the field are provided in Figure 6.

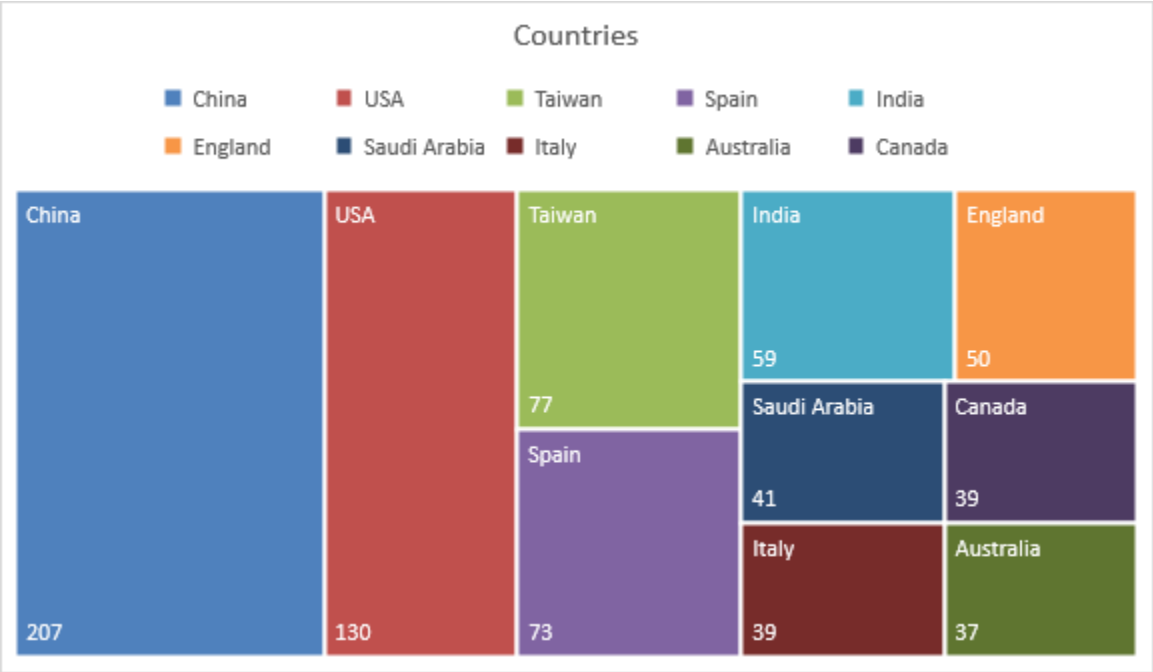

Figure 6. The Countries of Adaptive Learning Research in Distance Education

China plays a prominent role in the number of articles in this field, with 19.38% (n=207) of the articles coming from this country. The USA follows China with 12.14% (n=130) of articles. These two countries are followed by Taiwan with 7.19% (n=77), Spain with 6.82% (n=73), India with 5.51% (n=59), the United Kingdom with 4.66% (n=50), Saudi Arabia with 3.83% (n=41), Italy with 3.64% (n=39), Australia with 3.46% (n=37) and Canada with 3.36% (n=36).

The preference rate of adaptive learning in China is rapidly increasing. In the past 3 years, the number of individuals who have experienced adaptive learning has reached two million (Wang et al., 2023). This increase shows a growing trend especially in the fields of education and artificial intelligence (Huang et al., 2022; Yuan et al., 2023). Research topics in adaptive learning include neural networks, deep learning, reinforcement learning, and artificial intelligence, and focus on personalized and student-centered education (Peng et al., 2010; Wang, 2009). The evolution of adaptive learning research in China is evidenced by bibliometric analysis showing key research topics such as deep learning applications and intelligent tutoring systems. Adaptive learning has also become a growing trend in the United States, which focuses on tailoring educational experiences to individual students (Randi, 2022). This trend mostly involves dynamically adjusting course content to students' abilities, accelerating performance through automatic and instructor intervention (Capuano and Caballé, 2020; Dziuban et al., 2018). In addition, collaborative efforts between universities on this issue show that adaptive methods support the organization of the learning process in different disciplines and have a broader potential in education (Bordignon et al., 2021). Collectively, these findings indicate that there is a significant interest in adaptive learning strategies in the United States education sector and that these strategies are constantly being developed. On the other hand, the research on adaptive learning technologies has revealed new challenges and opportunities, with projects investigating the integration of adaptive learning with massive open online courses (Martin et al., 2020). A significant number of studies have been conducted in countries such as Spain, India, the United Kingdom, Saudi Arabia, Italy, Australia, and Canada, although they do not have specific educational policies on adaptive learning systems (Global Education Monitoring Report Team, 2024). These studies focus on the importance of adaptive strategies based on student models and content/instructional models (Capuano & Caballé, 2020).

Analysis of Co-authorship

Network analysis by researchers in the field of adaptive learning is an important tool for identifying diverse research groups and communities. This analysis helps us understand collaboration patterns, information flow, and the overall dynamics of the field. A total of 1071 publications were written by 3017 authors. The co-authorship network of authors who have at least 2 publications and 2 citations in their field is given in Figure 7.

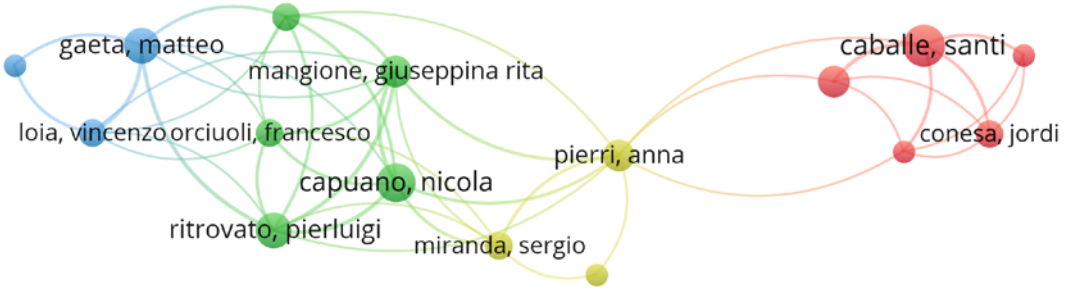

Figure 7. Co-authorship Network

As seen in the cloud, the authors who collaborated the most on publications are Capuano and Nicola, Ritrovato and Pierluigi, Cabelle and Santi, and Gaeta and Matteo. The notable network in the cloud is the central position of Pierri and Anna in terms of co-authoring with multiple authors.

The graph shows distinct clusters. This indicates the existence of different research groups or communities in the field of adaptive learning. Some nodes have more connections, such as "Mangione, Giuseppina Rita" and "Pierri, Anna". This suggests that they were central figures in the network, possibly leading research projects or acting to bridge the gap between different groups. Networks with fewer connections, such as “Gaeta, Matteo” and “Miranda, Sergio”, may represent newer researchers or those working on more specific topics. Some people, such as "Capuano, and Nicola", seem to connect different clusters. This suggests that they facilitate knowledge transfer and collaboration between groups. Cabella, Santi, is at the center of the red cluster on the right. This suggests that he played an important role in this research group and likely led or made significant contributions to many projects. Cabella and Santi's location may make it a bridge node with the potential to connect with other clusters. Its connection to “Pierri, anna” suggests that it can facilitate the flow of information and collaboration between two different research groups. Pierri, Anna serves as a connecting point between the different clusters. It has connections to the green cluster on the left, the red cluster on the right, and the yellow cluster at the bottom. This shows that he is skilled at collaborating and sharing knowledge with different research groups. Pierri Anna's connections to different clusters may indicate that she is interested in a wide range of research topics or is an expert in different methodologies. This makes it a valuable collaborator in the field of adaptive learning. As a result, network analysis by researchers in the field of adaptive learning offers important insights into collaboration, knowledge transfer, and the development of the field. This information can be used to make strategic decisions and allocate resources effectively to advance the field.

Co-author Countries

The cloud structure of the countries of co-authors who have been cited at least 5 times in at least 5 different publications is shown in Figure 8.

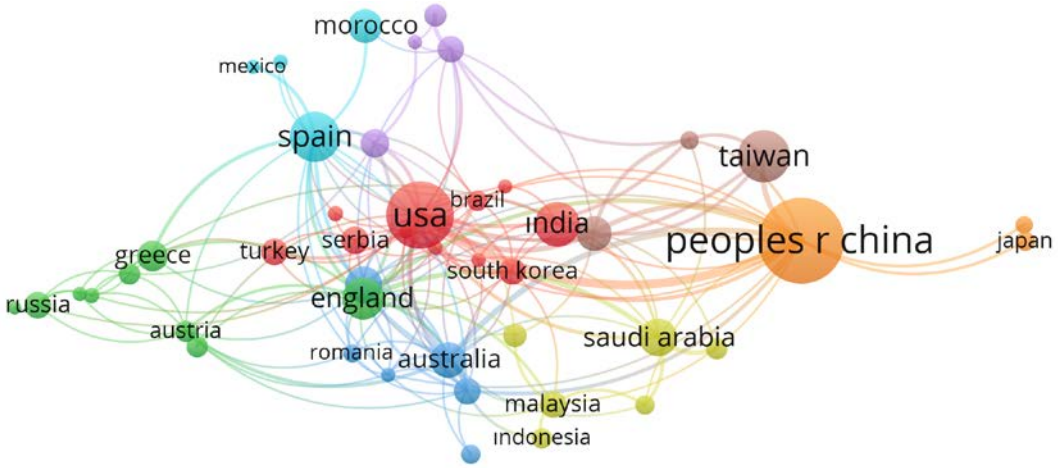

Figure 8. Cloud Structure Based on Countries of Co-Authors

When Figure 8 is examined and evaluated in the context of the countries of the co-authors, the People's Republic of China stands out as the country that makes the biggest contribution in this field. China is intensively researching and implementing distance education and adaptive learning. It has particularly strong connections with Taiwan, Japan, and South Korea. It also has important relations with North American and European countries. The USA is an important country in this field and has intense interaction with other countries. It also has strong connections with countries such as Australia, Brazil, India, and Italy. India attracts attention as a growing market and research center in distance education and adaptive learning. Spain plays an important role in this field in Europe and contributes to international cooperation and knowledge sharing. It has relations with countries such as Algeria, Morocco, Mexico and Greece. Taiwan (Taiwan) and Japan, as strong countries in the field of technology and education, are also effective in this field. Collaborations, research projects, and knowledge sharing between these countries contribute to the development of distance education and adaptive learning.

Cited Article Analysis

A total of 378 articles with at least 10 citations have found. The cloud structure related to these articles is shown in Figure 9.

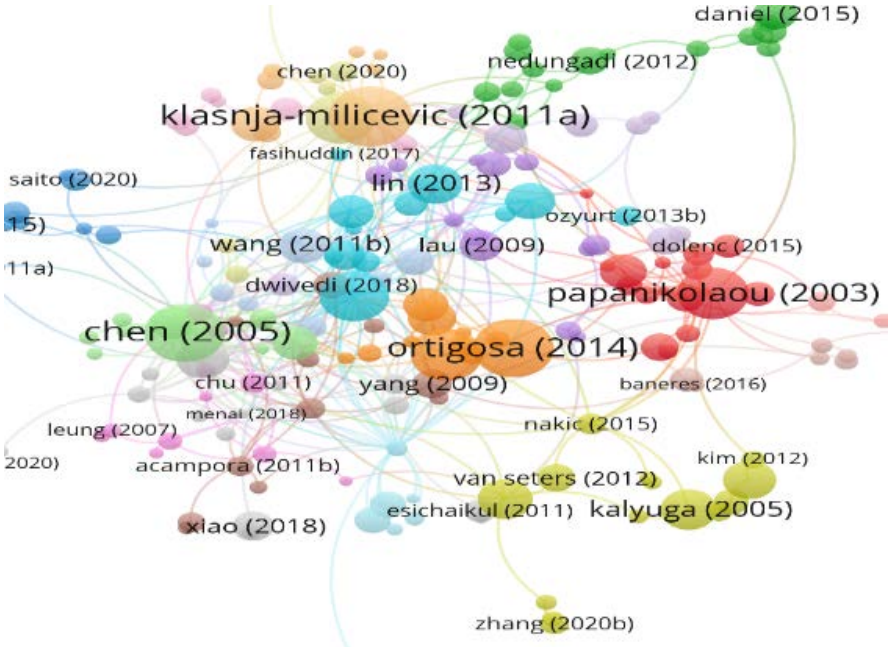

Figure 9. Cloud Structure of Cited Articles

Figure 9 shows the clustering structure of the resulting citation network. Different colors represent different research themes or communities. The general structure of the network shows that the field of adaptive learning has various subfields and research focuses. Some central nodes in the network have more connections than others. These nodes represent influential and highly cited articles in the field of adaptive learning. For example, articles such as "Chen (2005)", "Ortigosa (2014)" and "Papnikolaou (2003)" have a central position in the network and have made significant contributions to issues such as the design, evaluation, and pedagogical approaches of adaptive learning systems. There are also connections between clusters represented by different colors. This shows that there is collaboration and information flow between different research groups or communities in the field of adaptive learning. Such connections contribute to the integrated development of the field and the integration of different perspectives.

Citation Publication Analysis

Citation analysis reveals how publications in a particular research field are related to each other and which publications are more influential. It was determined that 134 articles out of 462 received at least 2 citations from at least 2 different articles. Figure 10 shows the cloud structure showing the most cited articles.

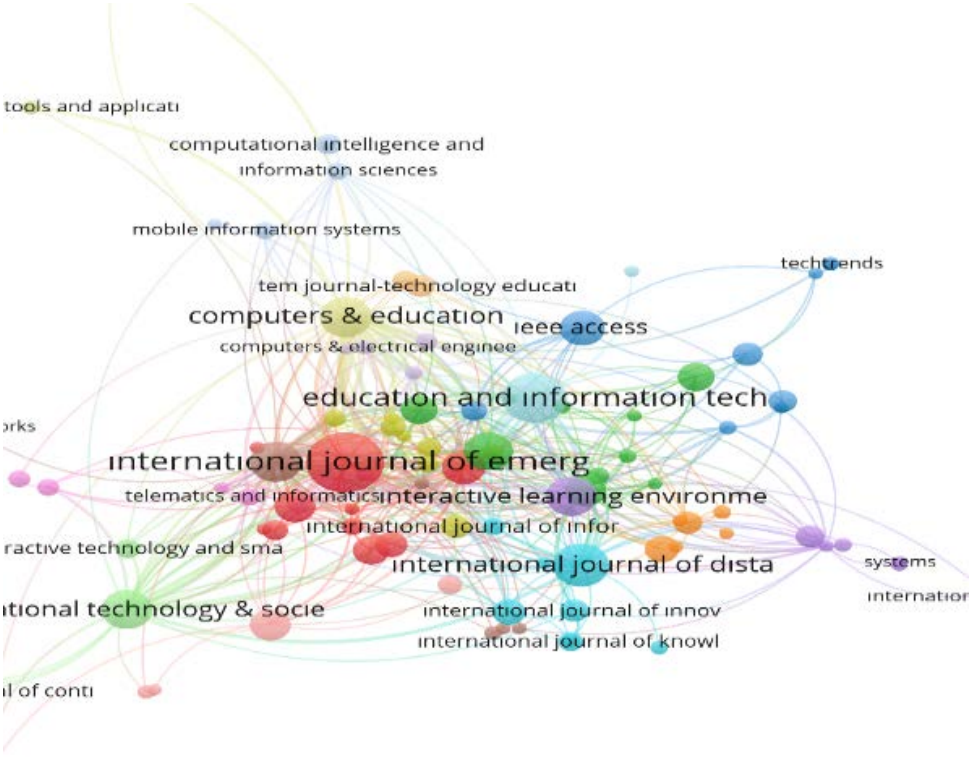

Figure 10. Cloud Diagram of the Most Cited Publications

When the table regarding the citation source analysis is examined, it appears that the publication with the most articles is Computers & Education (documents=23; citations=2031). The publication with the most articles was the International Journal of Distance Education (documents=50; citations=325). The publication with the fewest articles but the most cited was Academic Medicine (documents=2; citations=1260). There are 3 publications with over 1000 citations. These are Computers & Education (n=2031), Academic Medicine (n=1260), and Computers in Human Behaviour (n=1079) publications, respectively. The publications with the most articles are the International Journal of Emerging Technologies in Learning (n=50), Education and Information Technologies (n=34), and International Journal of Distance Education Technologies (n=26).

Publications such as "Computers & Education", "IEEE Access", "Education and Information Technologies" and "International Journal of Emerging Technologies in Learning" are centrally located in the cloud. These publications have a significant impact on the field and are highly cited. Different clusters have formed in the cloud. This may represent different research topics or subfields. For example, publications such as "Neural Networks" and "Computational Intelligence and Information Sciences" form one cluster, while publications such as "Educational Technology & Society" and "International Journal of Educational Technology in Higher Education" form another cluster. Some publications act as bridges the gap between different clusters. For example, the publication "Mobile Information Systems" addresses both the computer science and educational technology fields. Such publications facilitate the flow of information and collaboration between different disciplines.

Cited Author Analysis

Citation author analysis shows the authors within a specific research field who have received at least 2 citations in a minimum of 2 different articles and the collaborations between these authors. Out of 1071 articles, 312 authors meet these criteria. The cloud structure related to these authors is presented in Figure 11.

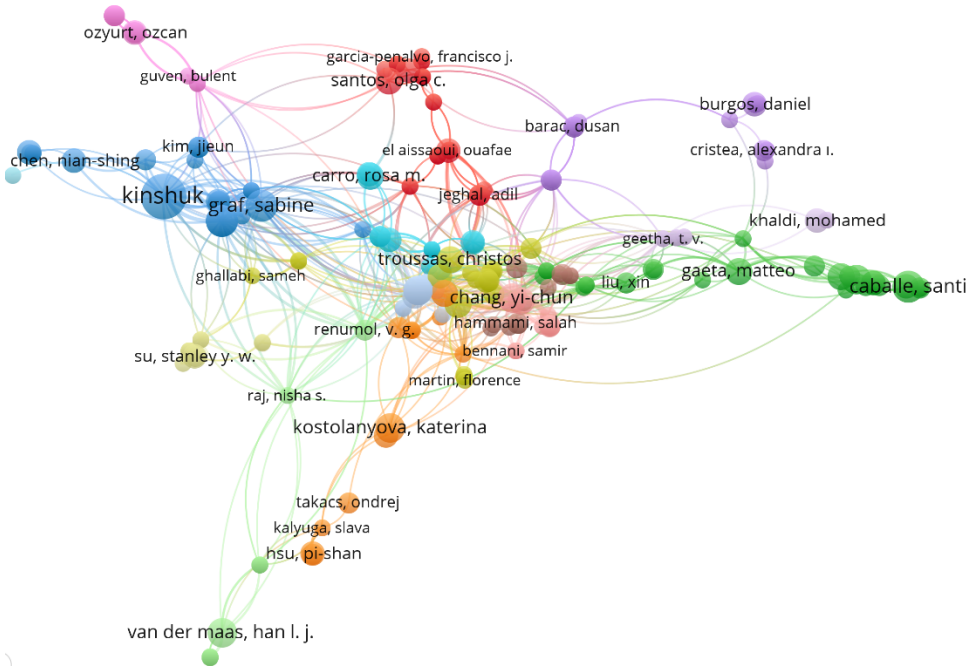

Figure 11. Cloud Diagram of Highly Cited Authors

The top three most cited authors are Chen and Chih-Ming (n=649), He and Haibo (n=459), and Chen (n=384), respectively. It is observed that the author with the most articles is Kinshuk (n=14). This author is followed by Essalmi and Fathi (n=7), Jemni and Mohamed (n=7), Graf and Sabine (n=7), and Caballe and Santi (n=7). When examining the publications regarding impact, it is noted that Chang and Yi-Chun authored the most impactful article.

In the cloud, authors such as "Kinshuk," "Chen, Nian-Shing," "Chang, Yi-Chun," and "Troussas, Christos" are positioned centrally. This suggests that these authors have significantly influenced the field and are frequently cited. Additionally, these authors appear to have extensive collaborations with other researchers. Different clusters have formed within the cloud, potentially representing various research groups or collaboration networks. For instance, the cluster surrounding "Kinshuk" and "Chen, Nian-Shing" may represent a large research group or collaboration network. The links in the cloud indicate collaborations between authors. While some authors have numerous collaborations, others have fewer, which may reflect different research cultures or collaboration strategies.

Keyword Analysis

This analysis examines the keywords used in 1071 articles within a specific research field, helping us understand the focal points, trends, and potential research areas of the field. The network shown in Figure 12 illustrates the relationships between the keywords of 257 articles that have at least three keywords.

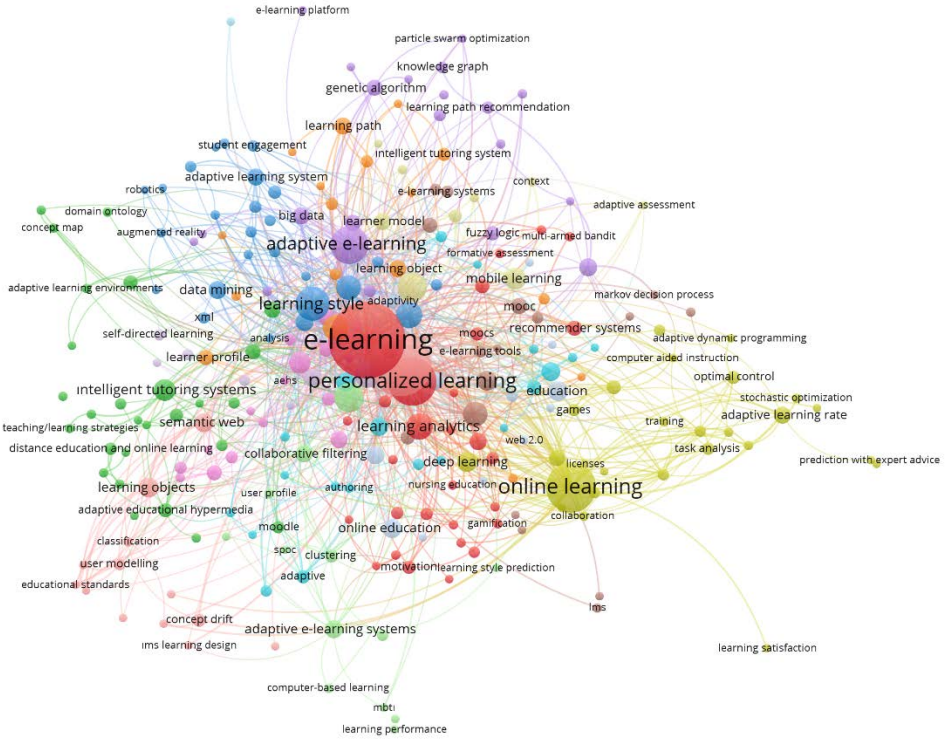

Figure 12. Network of Keyword Relationships

Keyword analysis visualization illustrates the interconnected nature of adaptive learning across various domains. It brings together various elements and concepts to understand the multi-faceted nature of modern education technology. It also serves as a rich resource for understanding interactions in educational technology. The most frequently used keyword in the articles is "e-learning" (n=220). This is followed by “adaptive learning” (n=146) and “online learning” (n=95). Keywords such as “e-learning”, “Adaptive E-Learning”, “Personalized Learning”, “Online Learning” and “Learning Analytics” are centrally positioned in the network. This shows that these issues are important and frequently researched in the field. Different clusters have formed in the network that may represent various research topics or subfields. For example, keywords such as “e-learning platform”, “learning management systems” and “mobile learning” form one cluster, while “adaptive learning environments”, “learning styles” and “learner modelling” form another cluster. Links between keywords show relationships between topics. For example, there is a strong connection between "e-learning" and "adaptive e-learning". This shows that adaptive learning is an important application area in e-learning. The existence of keywords such as "Machine Learning", "Deep Learning" and "Prediction" shows that artificial intelligence and learning analytics techniques are increasingly used in the field of education. Keywords such as "Personalized Learning", "Learning Styles" and "Learner Modelling" emphasize the importance of student-centered approaches and personalized learning systems. Keywords such as "Adaptive E-Learning", "Adaptive Learning Environments" and "Adaptive Assessment" show increasing interest in developing learning systems adapted to the needs of students. Keywords such as "Mobile Learning" and "M-learning" emphasize the increasing use of mobile technologies in education and the importance of research in this field.

Conclusions and Suggestions

This study has revealed significant developments in the field of adaptive learning by examining the trends, patterns, and outcomes of adaptive learning publications in distance education over the past two decades. The research shows a notable increase in publications on adaptive learning environments during the second decade of the 2000s. This increase reflects the growing importance of personalized and student-centred educational approaches to adaptive learning, which has evolved into a global understanding. Especially, the year 2022 experienced the highest number of publications, highlighting the rising interest in personalized learning. From an interdisciplinary perspective, educational research has emerged as the leading field, followed by computer science and engineering. Despite the priority given to educational pedagogy, the integration of technological dimensions is critical to optimizing learning paths and increasing engagement. This finding emphasizes the interdisciplinary structure of adaptive learning research, highlighting the importance of collaboration between the fields of education and technology. Considerable focus has been placed on eighteen authors in the field of adaptive learning in online education. It is particularly important to follow authors such as Kinshuk, Caballé, Santi, Capuano, Chen, Essalmi, Graf, Jemni, Tseng, Klasnja-Milicevic, Ivanovich, Daradoumis, Chang, and Van Der Maas to stay abreast of the field. Key topics such as learning styles, self-regulated learning, collaborative learning, the technology acceptance model, and reinforcement learning are areas that have attracted the interest of researchers, ensuring a comprehensive exploration of adaptive learning studies. The geographical distribution of publications emphasizes the global significance of adaptive learning research. Contributions led by China reflect various government initiatives aimed at promoting personalized learning environments, while the United States, Europe, and other countries also contribute to the research and implementation efforts. The higher prevalence of artificial intelligence and adaptive learning studies in China compared to other countries has placed the nation as a leading force in the field. Co-authorship network analysis has provided valuable insights into the structure of the research community, collaborative dynamics, and information-sharing networks within the realm of adaptive learning. Researchers aiming to work in this area should follow authors such as Nicola Capuano, Giuseppina Rita Mangione, Matteo Gaeta, Francesco Orciuoli, Pierluigi Ritrovato, Sergio Miranda, Anna Pierri, Santi Caballé, and Jordi Conesa. In studies on adaptive learning and distance education, researchers have established a wide international collaboration network. Researchers from countries such as China, the United States, Spain, India, and the United Kingdom have prominently emerged in this field, serving as central for intensive collaborations. Additionally, other countries such as South Korea, Brazil, Australia, and Saudi Arabia also stand out as significant nodes of connection. This diversity shows that adaptive learning and distance education are areas of global interest and collaboration. The most frequently cited articles were mostly published in the early to mid-2000s, indicating that adaptive learning was a rapidly developing field during this period. Furthermore, the most cited articles address various aspects of adaptive learning. While some articles focus on the design and development of adaptive learning systems, others examine the impact of adaptive learning on student achievement. Basic publications that researchers in this field should read include Chen (2005), Klasnja-Milicevic (2011), Lin (2013), Ortigosa (2014), and Papanikolaou (2003). Additionally, researchers interested in working in this field would benefit from publications such as Educational Technology & Society, Education and Information Technologies, and the International Journal of Emerging Technologies and Society. The most frequently cited authors include notable figures such as Kinshuk and Christos Trousas, indicating their significant influence in the fields of distance education and adaptive learning. Moreover, a strong connection has been observed among these authors. The most used keywords are "adaptive learning" "learning objects" "online learning" "e-learning" "personalized learning" and "learning analytics". Researchers aiming to work in this area should focus their studies on these keywords.

Research in the field of distance education and adaptive learning is continuously evolving and requires extensive investigation. Particularly, approaches that support self-regulated learning skills and enable students to determine their learning paths need to be developed. Understanding how

students perceive and accept adaptive learning systems is also crucial. Research utilizing frameworks such as the Technology Acceptance Model can provide insights into the factors influencing adoption and can help identify strategies to enhance system acceptability.

The integration of artificial intelligence and machine learning techniques into adaptive learning systems has significant potential. These technologies can be used to more accurately predict student performance and provide personalized learning experiences that address individual needs and learning styles. To increase the impact of adaptive learning systems, researchers should use learning analytics techniques to analyse student data and evaluate system performance. This data-based approach can provide awareness for system improvements and increase student academic success.

Adaptive learning systems can be integrated into educational environments by adapting content and navigation. Adapting content is presenting the content of the environment in a way that is appropriate for the student in line with student information, goals, and other characteristics. Examples of adapting content include showing a limited section of the content to a low-readiness student and the entire content to a high-readiness student, or providing links that allow for additional explanations about a title to be presented as pop-up windows or extended text on the same page (Brusilovsky, 1998). Similarly, by dividing the components that make up the content into sections, different content can be prepared for students for each section. Thus, it can be decided which content will be displayed with each section according to student characteristics. Different presentations of the same content for each page can be created, and appropriate presentation types can be prepared in line with student characteristics. In adapting navigation, the student can be helped to find the next most appropriate topic in line with his/her goal and other factors presented in the student model. A button such as “Next” or “Continue” can be created dynamically, allowing the user to access the next link. For students with low readiness, navigation space can be limited by hiding links to comprehensive content pages. There are findings in the literature that adaptive environments reduce the number of navigation steps, navigation time, and the feeling of getting lost in content, increase academic success, and encourage nonlinear navigation for students with low readiness (Brusilovsky & Pesin, 1998).

The architectures of adaptive learning systems usually follow a multi-layered structure. Components such as the student model, domain model, and pedagogical model form the basis of the system. For example, a student model can predict the student's knowledge level and learning style with techniques such as Bayesian networks or hidden Markov models. The collection, processing, and storage of student data also bring about privacy and security issues. In the context of learning analytics, data privacy and ethical issues should be addressed. Compliance with data protection regulations such as GDPR should be prioritized in system design (Ferguson, 2012). Agile software development methodologies are frequently used in the development of adaptive learning systems. These methodologies enable the system to be developed quickly and adapt to changing needs (Pressman, 2010). Cloud-based architectures increase the scalability of adaptive learning systems. Continuous integration and continuous delivery (CI/CD) practices facilitate the maintenance and update of the system. These applications increase the stability and reliability of the system by providing automated testing and deployment processes.

Encouraging international partnerships among researchers working in the field of distance education and adaptive learning can lead to a better understanding of diverse learning experiences across cultures and contexts. Establishing research networks that bring together experts in the field can create a dynamic environment for knowledge sharing, collaborative projects, and the generation of innovative research ideas. By adopting these suggestions, researchers can contribute to the persisting development and implementation of effective adaptive learning solutions in distance education.

Author Contribution

Bülent Kandemir, performed the bibliometric analysis and data visualization process. *Necati Taşkın,* performed the PRISM process and data collection process. The authors co-wrote, read, and approved the manuscript.

Ethic

There are no ethical issues regarding the publication of this article.

Conflict of Interest

The authors state that they have no conflict of interest.

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