The Trends in Adaptive Learning Research: A Bibliometric Analysis Study

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The purpose of this study is to identify the trends in research on adaptive learning. Using a survey method, the research articles related to adaptive learning have been analyzed through bibliometric techniques based on publication, authorship, journal, country, and keywords in the Web of Science Core Collection database. The analysis has revealed that the publication with the highest network centrality is (2012), the publication with the most citations is Hwang (2008), and the most cited publication is Felder's (1988) study. It has been found that Daniel Burgos has the strongest network and the largest number of collaborations, Gwo-Jen Hwang has the most connections, and Peter Brusilovsky is the most cited/quoted author. The journal with the highest network centrality and citations is Computer & Education, and Education and Information Technologies has the strongest citation relationship after 2018. The country with the most connections and citations is the United States, and the most frequently used keywords in the research are e-learning, higher education, and motivation.

INTRODUCTION

With the emerging technologies, the necessity of preparing educational environments and conditions that can adapt to different education purposes and different skills individually has emerged (Corno & Snow, 1986). What Dewey (1902) and Thorndike (1911) also revealed is the necessity of emphasizing the importance of considering individual needs and differences in education (as cited in Park & Lee, 2008). Reigeluth's (1996) statement, "One size does not fit all.", points out that individuals with different characteristics (personality, learning style, learning needs, information processing, etc.) will be in the same environment, and individuals will have different ways of learning (Riding & Rayner, 1998). "Personalized learning," "individualized instruction," "customized learning," and "adaptive learning" have emerged as new concepts as a result of the importance of learner differences. To shortly define them, personalized learning is a learning process that is used to support and encourage learning outcomes, tailored to the abilities, interests, and needs of learners and adapted to their lives, experience, knowledge, and areas of interest, where they can relate to the process, content, and products (Grant & Basye, 2014, Santally & Senteni, 2005). Individualized instruction is considered an approach that personalizes the material by taking into account the specific needs and goals of the individuals to be addressed during teaching, while customized learning refers to a learning plan that takes into account individual differences and needs, characteristics, interests, and academic mastery (Shemshack & Spector, 2020). Adaptive learning is an instructional approach that enables the customization of educational materials and learning encounters based on individual attributes, learning preferences, and student performance. By tailoring the learning experience to meet specific needs, this method enhances students' learning efficacy and facilitates improved academic outcomes.

Corno and Snow (1986) define adaptive teaching/learning as the use of approaches and techniques that will meet the learning needs of each individual. Özkeskin (2017) defines adaptive learning as applications where the learning process is differentiated by taking into account the individual characteristics, needs, and learning behaviors of the learners. Brusilovsky (1998) defines advanced hypermedia systems that structure the instruction by creating a model for the student by their goals, interests, and preferences, and personalizing the instruction for each student as adaptive learning environments.

Until the mid-1800s, adaptation in teaching was accepted as a general teaching method (Reiser, 1987). Nowadays, adaptive learning is a learning method that aims to reach the target level in comprehending knowledge and ensuring continuity by taking into account the unique features of each individual and benefiting from information and communication technologies, and it continues to gain prominence as an increasingly important concept.

In today's world, the adaptation of learning processes according to the learner's characteristics, interests, and needs has become easier thanks to rapidly evolving information and communication technologies (Park & Lee, 2004). Numerous studies have been conducted on adaptive learning, which has its roots dating back to the 4th century and is utilized by many giant companies such as NASA, Amazon, Netflix, and others (Park & Lee, 2008). There are adaptations made in these studies based on different individual characteristics and preferences. Learning styles (De Bra et al., 2013; Despotović-Zrakić, et al., 2012), personality types (Despotović-Zrakić et al., 2012; Kim et al., 2013), cognitive styles (Yang, et al., 2013), prior knowledge level

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(Çelebi, 2014; De Bra et al., 2013), intelligence (Kelly, 2005), and learning goals (De Bra et al., 2013) are some of the prominent individual characteristics found in these studies.

By taking into consideration each student's particular qualities, adaptive learning primarily aims to increase the success of the learning process. The educational content and instructional strategy are chosen using this method's analysis of the student's prior knowledge level, learning style, interests, and strengths and limitations. Studies on adaptive learning have shown that these systems can aid in students' learning and significantly raise their accomplishment levels. In this context, computer scientists and cognitive scientists are working to develop adaptive learning environments and systems by utilizing artificial intelligence to produce interactions similar to those in face-to-face education (Wang et al., 2020). This is due to the growing usage of computers and the Internet. Artificial intelligence, which tracks and evaluates students' performance and analyzes their characteristics, can create better-personalized learning materials.

All adaptive learning systems follow a similar pattern. This pattern proceeds by predicting the progress of learners based on the data collected from them, suggesting new learning activities, and providing feedback. The type of knowledge to be learned (cognitive, emotional, etc.), the characteristics of the learners (knowledge level, emotion, motivation, etc.), and the features of the learning activities are all factors that need to be taken into consideration during the process (Park and Lee, 2008). Students can develop their independence as learners with the use of adaptive learning. Due to the more personal nature of learning experiences, students may show higher motivation and interest levels, which can also help students to develop themselves further. Adaptive learning environments are systems that autonomously provide options to support the learning experience based on learners' characteristics. Therefore, the design of the content and interface that best suits the learners is crucial in terms of the quality of instruction. An ideal adaptive learning environment consists of the following components: content/domain model, learner/user model, instructional model, and adaptation mechanism (Somyürek, 2009). The content/domain model involves determining subject areas that are suitable for learners' learning needs, prior knowledge levels, and goals, as well as deciding on appropriate learning objects and presentation formats. The learner/user model includes the identification of learners' prior knowledge levels, demographic, individual, and cognitive characteristics, and learning styles. For example, analyzing the user's search and navigation behaviors, and determining sensory preferences such as visual and auditory preferences are some examples of how it works. The instructional model is the stage where pedagogical choices suitable for learning goals are made by synthesizing the user model and content model. The adaptation mechanism consists of protocols and algorithms that bring together the user, content, and instructional models, allowing the system to be personalized according to the user's characteristics. Additionally, adaptations are typically carried out within the scope of the basic strategies of content adaptation and navigation adaptation.

Adaptive learning provides a more effective learning experience by offering learning materials and methods that are suitable for students' characteristics. This method, increasingly widespread due to technological advancements, also allows students to become more independent learners. In the literature, it is evident that numerous studies have been conducted on adaptive environments designed to enhance individuals' learning by considering various variables and employing different methods/techniques. Akbulut and Cardak (2012), who conducted a summary and content analysis of these studies, examined 70 studies and emphasized that learning styles were the most commonly used variables, especially in learner modeling, during the development of adaptive learning environments. According to this study, the most frequently used learning styles in learner modeling are Cognitive styles, Felder-Silverman's learning styles, Kolb's learning styles, Honey and Mumford's learning styles, and VARK learning styles.

In their study, Raj and Renumol (2022) conducted a systematic literature review on learning content recommenders in adaptive and personalized learning environments from 2015 to 2020. They examined 52 studies in this area. The reviewed studies revealed that learners' learning styles, preferences, knowledge levels, and other cognitive aspects were predominantly utilized. Various approaches such as collaborative filtering, content-based filtering, ontological approaches, etc. were observed to be employed in learning content recommendation within adaptive learning environments.

In their study, Xie et al. (2019) examined 70 articles published between 2007 and 2017 in 6 SSCI-indexed journals related to technology-enhanced adaptive/personalized learning. They analyzed these articles from the perspectives of learners, learning content, learning support/hardware, learning outcomes, and adaptive/personalized parameters. The findings of their study revealed that the participants in the examined

articles were predominantly higher education students. Engineering/computer was the most popular subject in terms of learning content. Affection and cognition were the most frequently achieved learning outcomes in these studies. Learners' preferences, learning achievements, profiles, and personalized data sources such as learning logs became key parameters to support adaptive learning. It was highlighted that the majority of studies related to adaptive learning still primarily supported traditional computers or devices. However, with the rapid development of artificial intelligence, virtual reality, cloud computing, and wearable computing, adaptive learning has significant potential applications in wearable devices, smartphones, and tablet computers.

Somyürek (2015), who examined new approaches in adaptive educational hypermedia, emphasizes that the following topics are the most popular new trends: standardization (metadata, specifications), semantic web (ontology, query language), modular frameworks (learning objects, LMS/LCMS, agents, learning object repository, user model server), data mining (clustering, classification), machine learning technologies (neural networks, fuzzy logic, naive Bayes classifiers), social web, and device adaptation. Based on the studies, it is considered important to investigate trends related to adaptive learning. In this study, the trends in research related to adaptive learning are attempted to be identified in the context of publication, author, journal, country, and keywords.

The following research questions have been addressed in the study:

Publication

What is the publication and citation relationship of studies related to "Adaptive Learning " in the articles indexed in the Web of Science Core Collection (WoSCC) database?

What is the common citation relationship in studies related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

How is the bibliometric coupling relationship network in publications related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

Author

What are the authors and their collaborations in the studies related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

What is the authorship and citation relationship of studies related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

What is the common citation relationship among the cited authors in studies related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

How is the bibliometric coupling relationship network among the authors in studies related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

Journal

In studies conducted on "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database, what is the relationship between journals and citations?

What is the common citation relationship among the referenced journals in articles indexed in the Web of Science Core Collection (WoSCC) database regarding "Adaptive Learning"?

How is the network of bibliometric coupling among journals in studies conducted on "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

Country

What are the countries and collaborations involved in studies related to "Adaptive Learning" in articles indexed in the Web of Science Core Collection (WoSCC) database?

How is the citation relationship among countries in studies conducted on "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

What is the network of bibliometric coupling among countries in studies conducted on "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

Keyword

What are the common keywords in studies conducted on "Adaptive Learning" in articles indexed in the Web of Science Core Collection (WoSCC) database?

METHOD

In this study, a structural analysis of articles written on adaptive learning was conducted to uncover the trends in studies related to adaptive learning. To achieve this goal, a survey method was designed, and data

were examined through mathematical and statistical methods to measure the performance of scientific elements and analyzed using mapping techniques to visualize the examined structure. Bibliometric analysis, defined as the analysis through bibliometric methods (Şimşir, 2021), was employed to investigate the data.

Data Collection

In this study, the Web of Science Core Collection (WoSCC) database was utilized to search for articles that mention the concept of "adaptive learning" in the subject field. The articles were specifically located within the Education - Educational Research and Education Scientific Disciplines Web of Science Categories, with the document type set as "article." The search was conducted across the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), and Emerging Sources Citation Index (ESCI) indexes, resulting in a total of 2136 articles obtained up until the year 2022. A bibliometric analysis was subsequently conducted on these articles. The criteria employed for the selection of research data are presented in Table 1.

Table 1. Research Criteria

Research Criteria	
Topic	Adaptive Learning
Web of Science Categories	Education-Educational Research or Education Scientific Disciplines
Document Types	Article
Databases	• Web of Science Core Collection (WoSCC): • Science Citation Index Expanded (SCI-EXPANDED) • Social Sciences Citation Index (SSCI) • Emerging Sources Citation Index (ESCI) • Arts & Humanities Citation Index (A&HCI)

Data Analysis

Bibliometric analysis is a method that is increasingly popular in various fields, particularly in business and economics, and involves the examination of bibliometric data (publications, citations, etc.) through quantitative techniques such as citation analysis (Donthu et al., 2021). Performance analysis, which examines the contribution of scientific elements to a specific field, and scientific mapping, which demonstrates the relationships between elements, are among the bibliometric analysis techniques (Donthu et al., 2021). Additionally, enrichment techniques are employed in bibliometric studies to enhance the results of the analysis (Donthu et al., 2021). Figure 1 summarizes the main components of bibliometric analysis utilized in this research.
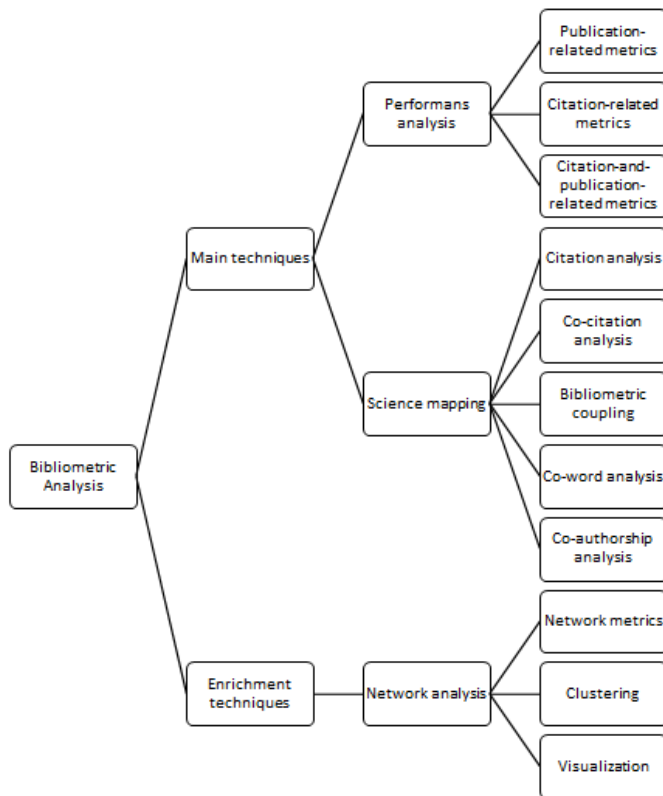
Figure 1. The bibliometric analysis toolbox (Donthu et al., 2021)

In this study, the articles obtained from the WoSCC database, based on the defined criteria, were imported into VOSviewer software (version 1.6.18) to conduct bibliometric analyses under the main headings of publications, authors, countries, journals, and keywords. Bibliometric analysis techniques, including citation analysis, co-citation analysis, bibliometric coupling, co-word analysis, and co-authorship analysis, were employed to examine the structure and trends of the research topic. These techniques aim to reveal the distribution of authors, institutions, countries, publications, and citations, thereby facilitating scientific mapping (Donthu et al., 2021).

- *Citation analysis:* It is used to identify the most influential publications, authors, or journals in a field and analyze the relationships among publications (Donthu et al., 2021). It involves analyzing the number of citations for documents, sources, authors, organizations, and countries.
- *Co-citation analysis:* It is employed to understand the development of key topics in a field by examining the relationships among publications that are commonly cited together, as well as exploring the cited journals, authors, or references (Yang et al., 2020; Donthu et al., 2021). By analyzing cited references, cited sources, and cited authors, the frequency of citations between two studies can be determined.
- *Bibliometric coupling:* This analysis aims to understand the temporal or current development of topics in a field by examining the relationships among publications that cite the same sources from different origins and matching their references (Rehn et al., 2008; Donthu et al., 2021). The number of shared references demonstrates the strength of the relationship between publications. It involves analyzing documents, sources, authors, organizations, and countries to identify studies that cite the same work.
- *Co-word analysis:* It focuses on the written content of publications to discover existing or future relationships between topics in a field (Donthu et al., 2021). It involves analyzing the frequency and associations of concepts and keywords found in the titles, abstracts, and keywords of studies (Callon, et al., 1991; Su & Lee, 2010).
- *Co-authorship analysis:* It examines the coexisting equivalent effects, authors, and connections (institutions, countries) that contribute to the development of a field (Donthu et al., 2021). In co-authorship analysis, the collaboration networks among authors, their affiliations, and the countries where their institutions are located are investigated to shed light on the collaborative dynamics

within the dataset (Schubert & Glänzel, 2006; Zhang et al., 2014; Ponomariov & Boardman. 2016; Wang et al., 2014; Yan & Guns, 2014).

FINDINGS

The research findings obtained from the conducted analyses have been presented by classifying them in terms of publications, authors, countries, journals, and keywords.

A. Publication

1. What is the publication and citation relationship of the studies related to "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

"Citation Analysis" Publication-Citation Network:

In the articles indexed in the WoSCC database, a citation analysis (documents) was conducted using VOSviewer for the studies related to "adaptive learning" that received a minimum of twenty citations from a total of 2136 publications. Out of these, 392 publications were identified and included in the analysis. Publications with a total link strength of 0 were excluded from the mapping. An analysis of the publication-citation network was performed on 146 interconnected publications. There are 19 clusters identified as interconnected sets of elements, with a total of 260 connections between them.
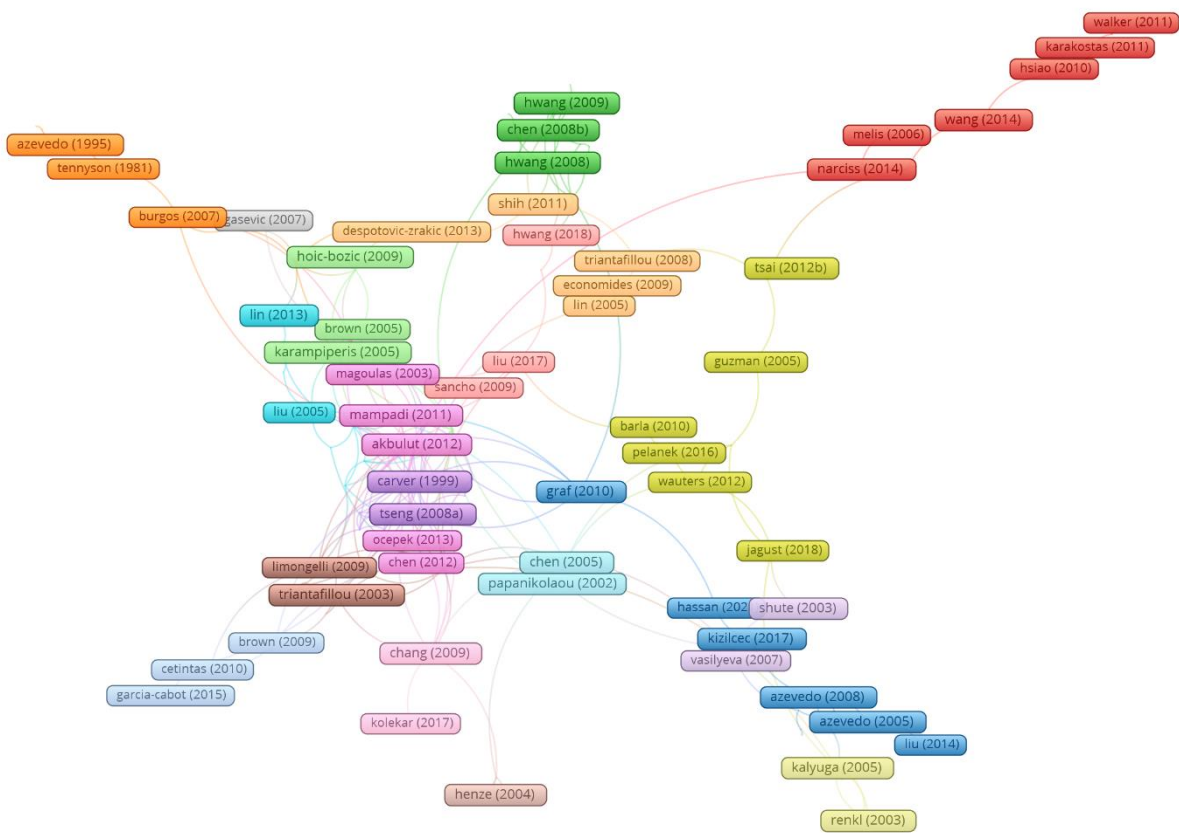

Figure 2. Publication-Citation Network

In the publication-citation network depicted in Figure 2, the publication with the highest degree of centrality is the study by Akbulut (2012), which has 21 connections and 149 citations. The publication with the highest number of citations is Hwang (2008), which has received 300 citations and has 8 connections in the network. The top 10 publications with the highest number of connections in the citation network are presented in Table 2.

Table 2. Ranking of Publications and Citations Based on Total Link Strength

Publication	Number of Citations	Total Link Strength
Akbulut (2012)	149	21
Carver (1999)	245	17
Yang (2013)	103	14
Nakic (2015)	27	14
Tseng (2008a)	162	13
Hwang (2012)	131	11
Chang (2009)	91	9
Hwang (2013)	60	9
Chen (2005)	277	9
Somyürek(2005)	20	8

2. In the articles indexed in the Web of Science Core Collection (WoSCC) database, what is the common citation relationship among the studies related to "Adaptive Learning"?

"Co-citation Analysis" Cited References:

In the articles indexed in the Web of Science Core Collection (WoSCC) database, a Co-Citation Analysis (cited references) was conducted using VOSviewer for the studies related to "adaptive learning". The analysis revealed a total of 70,547 publications. To identify the most cited/referenced studies, 91 publications that received a minimum of twenty citations were included in the analysis. In Graph 1, the top 10 publications based on the total number of citations received by each publication are listed in descending order.
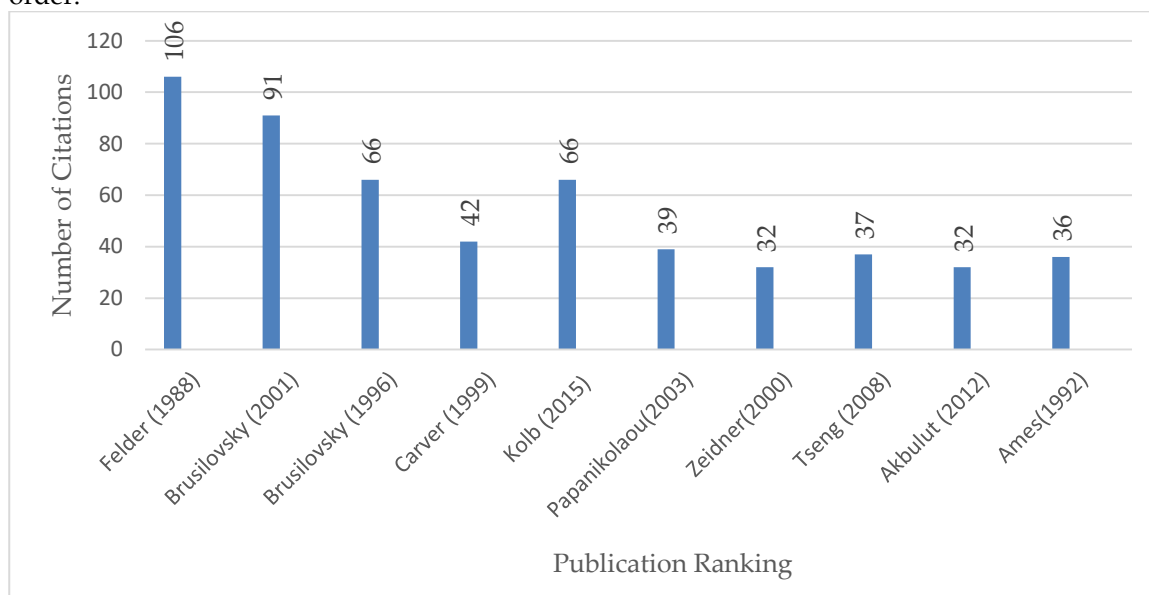
Graph 1. Top 10 Most Cited Publications

According to Graph 1, the study by Felder (1988) is the most cited publication with 106 citations and a total link strength of 441. Following that, the studies by Brusilovsky (2001, 1996), Carver (1999), Kolb (2015), Papanikolaou (2003), and Zeidner (2000) have been identified as the most highly cited ones based on total link strength.

When the cited publications were examined using visual mapping techniques, a network of connections, as shown in Figure 3, was obtained.
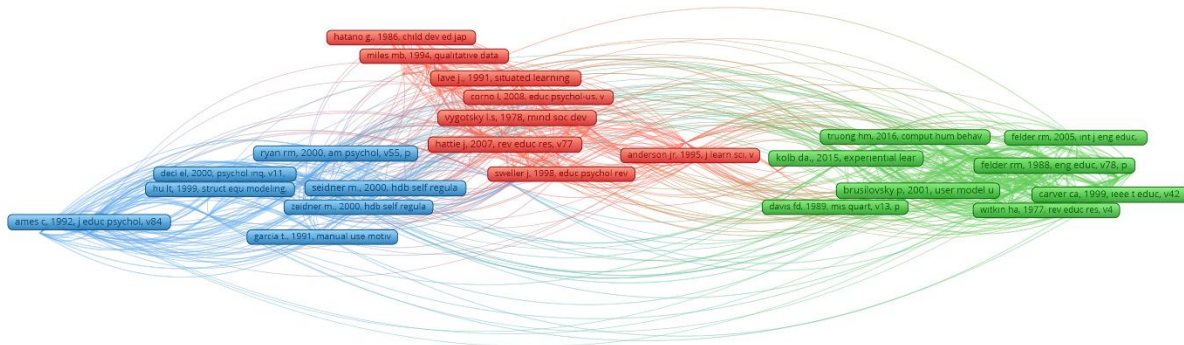
Figure 3. Cited Publication Network

According to Figure 3, the Co-Citation Analysis - cited references analysis revealed three clusters. The first cluster consists of 35 studies, the second cluster consists of 32 studies, and the third cluster consists of 24 studies that are linked together. In the first cluster, shown in red in Figure 3 Vygotsky's (1978) study entitled "Mind in Society: Development of Higher Psychological Processes" has 57 connections, while Lave, J.'s (1991) study entitled "Situated Learning" has 39 connections. These studies in the first cluster primarily focus on learning. In the second cluster, visualized in green, Felder, R.M.'s (1988) study on engineering education has the highest link strength with 42 connections, followed by Bruslovsky, P.'s (2001) study on learner modeling with 62 connections, and Carver, C.A.'s (1999) study on hypermedia and learner cognition with 35 connections. The studies in the second cluster predominantly revolve around engineering and computer science. In the third cluster, visualized in blue, Ames, C. (1992), Zeidner, M. (2000), and Ryan, R.M. (2000) have studies with 28, 54, and 54 connections, respectively. The studies in the third cluster focus more on psychology and educational psychology.

3. How is the bibliometric coupling relationship network in publications related to "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?
"Bibliometric Coupling" Publication- Bibliometric Coupling Network:

A bibliometric coupling (documents mapping) was carried out in the studies on "adaptive learning" in the Web of Science Core Collection (WoSCC) database using VOSviewer. A total of 2,136 papers were found, and the mapping comprised 380 publications with at least 20 citations. Eight clusters make up the network map. The first cluster contains 107 publications, whereas the second cluster has 86 publications, the third cluster has 80, the fourth cluster has 54, the fifth has 42, the sixth has 7, the seventh has 2, and the eighth has 2.
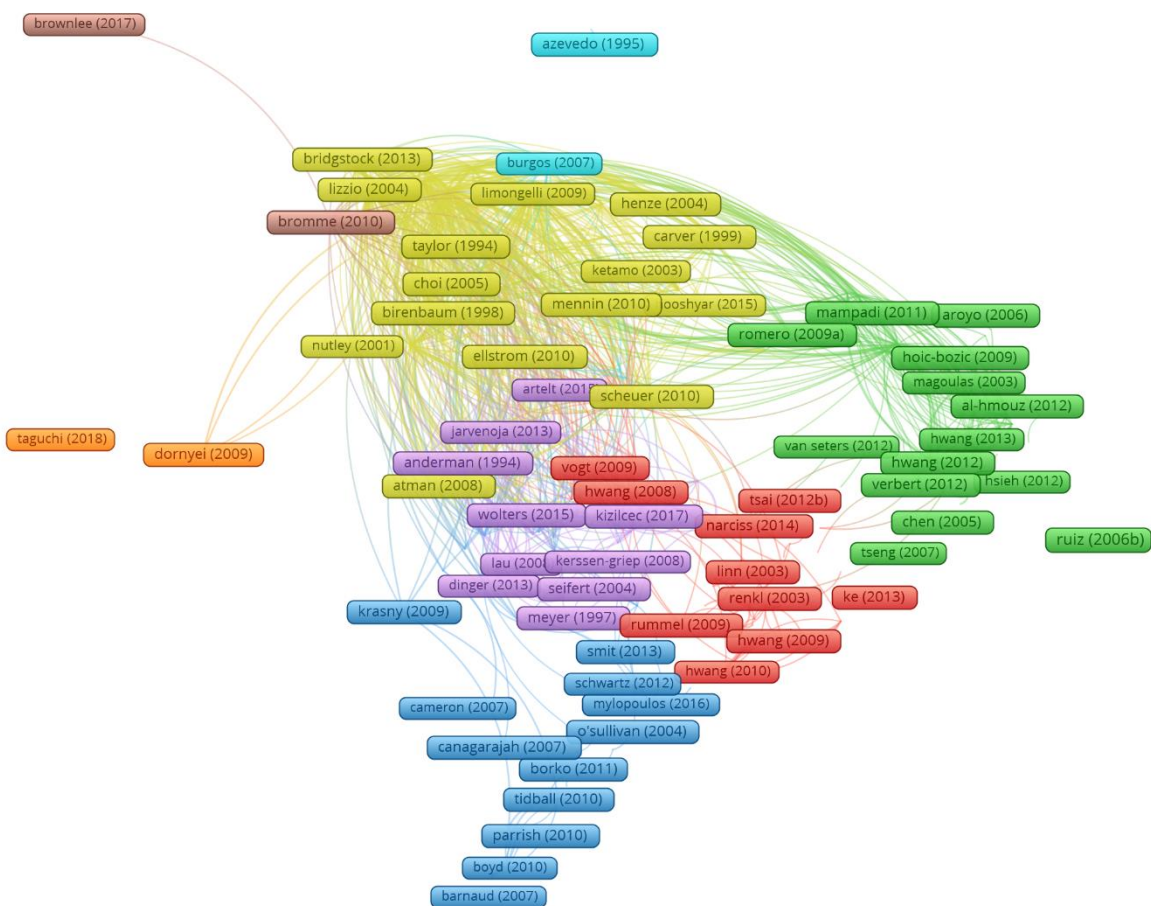
Figure 4. Publication- Bibliometric Coupling Network

According to Figure 4, there is a publication-bibliometric coupling network. In this map, the 1st cluster, represented by red, contains a larger number of publications, while the publication with the highest number of citations (1093 citations), represented by green, is found in the 2nd cluster. The publication with the highest total link strength in terms of bibliometric coupling network (134 networks), represented by yellow, is located in the 4th cluster (Brinton, 2015).

B. Author

1. How are the authors and their collaborations working on "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

"Co-authorship Analysis" Author Collaboration Network:

In the Web of Science Core Collection (WoSCC) database, a Co-authorship Analysis (authors) was conducted using VOSviewer to examine the studies related to "adaptive learning." A total of 5,524 authors were identified in the mapped analysis, with 185 authors included in the mapping who had a minimum of three publications. Authors who had no collaboration with each other and had a total link strength of 0 were excluded from the mapping. A network analysis of author collaboration was conducted using 24 authors who were connected. There are a total of 47 relationships between these authors. There are four clusters on the network map, with the first cluster having eight writers, the second having seven, the third having six, and the fourth having three.
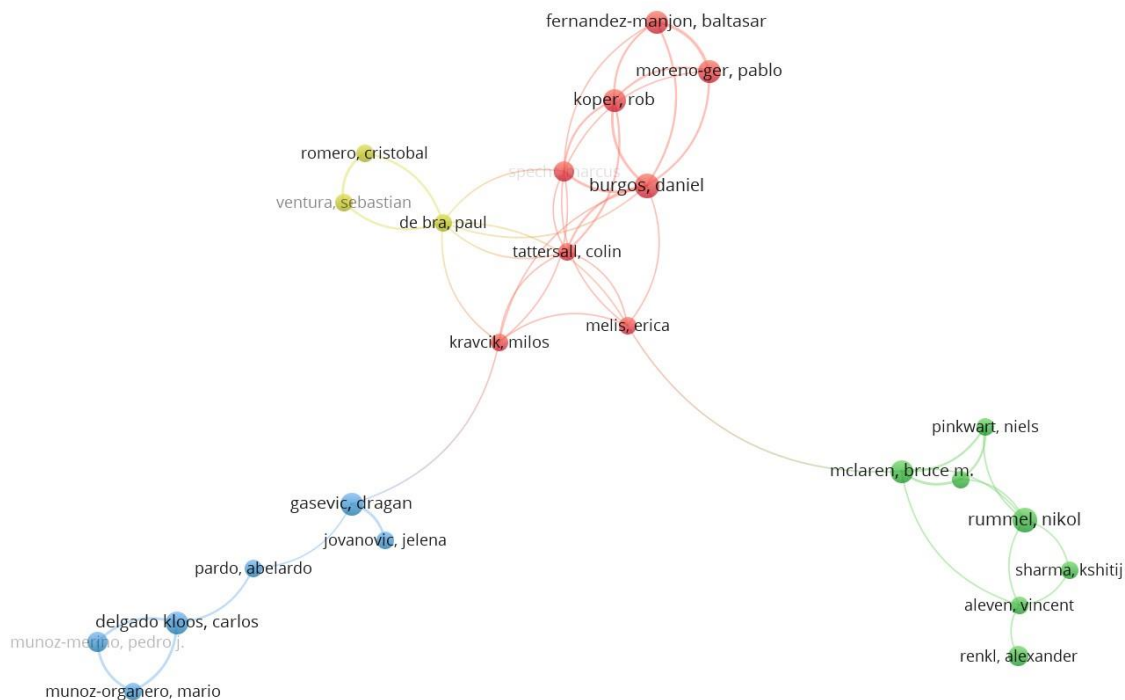
Figure 5. Author Collaboration Network

In Figure 5, it is observed that Daniel Burgos has the strongest network with 8 links and a total link strength of 15 in the resulting relationship network. He is also the most collaborative author in the network. Additionally, Daniel Burgos has a publication or publications related to "Adaptive Learning" with 96 citations.

2. What is the authorship and citation relationship of studies related to "Adaptive Learning" in the Web of Science Core Collection (WoSCC) database?

"Citation Analysis" Author-Citation Network:

In the Web of Science Core Collection (WoSCC) database, a Citation Analysis (authors) was conducted using VOSviewer to examine the studies related to "adaptive learning." A total of 5,524 authors were identified in the analysis, with 185 authors included in the mapping who had a minimum of three publications. From the set of interconnected items, 129 authors were selected, forming 12 clusters with a total of 361 connections among them. The network map consists of twelve clusters, with the first cluster having fifteen authors; the second and third having fourteen each; the fourth, fifth, and sixth having thirteen each; the seventh having eleven; the eighth having ten; the ninth, tenth, and eleventh having seven each, and the twelfth having five authors.
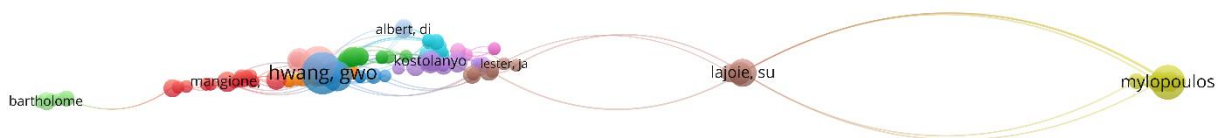

Figure 6. Author Citation Network

In the relationship network depicted in Figure 6, upon examining the citation relationships among the authors, it is observed that Gwo-Jen Hwang in the 3rd cluster has the most connections with 39 links. Gwo-Jen Hwang has 19 publications related to "Adaptive Learning" and these publications have received a total of 1381 citations.

3. What is the co-citation relationship of cited authors in studies on "Adaptive Learning" in articles indexed in the Web of Science Core Collection (WoSCC) database?

"Co-citation Analysis" Cited Authors:

In the Web of Science Core Collection (WoSCC) database, a Co-citation Analysis (cited authors) was conducted using VOSviewer to examine the studies related to "adaptive learning." A total of 44,317 authors

were identified in the analysis, and 379 authors who had a minimum of twenty citations were included in the analysis to determine the most cited studies. From the set of interconnected items, the analysis resulted in six clusters. The first cluster consists of 112 authors, the second cluster consists of 93 authors, the third cluster consists of 59 authors, the fourth cluster consists of 54 authors, the fifth cluster consists of 51 authors, and the sixth cluster consists of 10 authors.
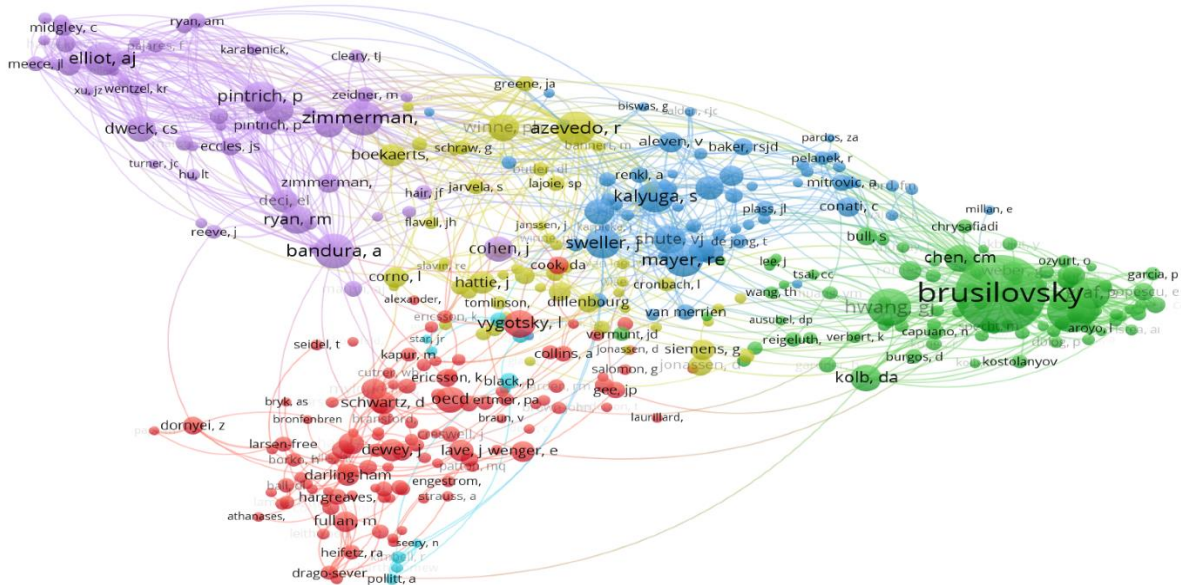

Figure 7. Cited Authors Network

Upon examining Figure 7, it is observed that the following authors are among the most cited authors in their respective clusters:

Cluster 1: J. Dewey, L. Vygotsky, and K.A. Ericson
Cluster 2: P. Brusilovsky, G.J. Hwang, and S. Graf
Cluster 3: R. Mayer, V. Shute, J. Anderson, and S. Kalyuga
Cluster 4: R. Azevedo, P. Winne, S.P. Lajoe, and M. Chi
Cluster 5: B.J. Zimmerman, A. Bandura, and P. Pintrich
Cluster 6: R. Kimbell, A. Pollitt, and P. Black

In Graph 2, the most cited authors are ranked in descending order based on the total number of citations they have received.
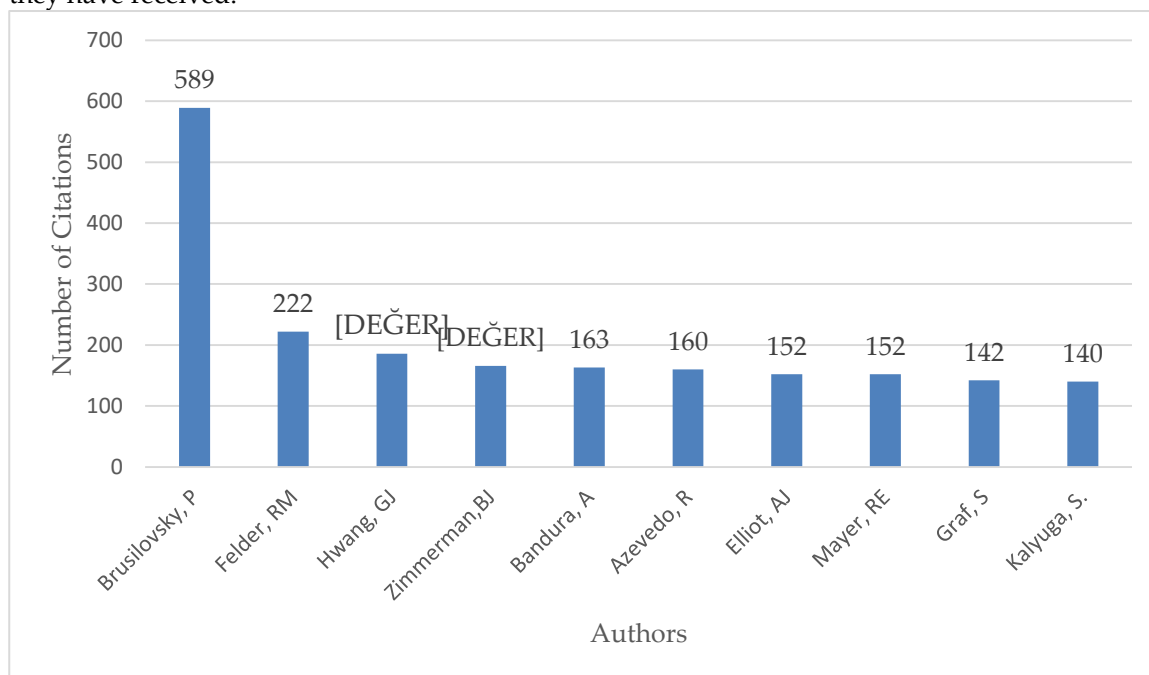
Graphic 2. Top 10 Most Cited Authors

Upon examining Graph 2, it is observed that P. Brusilovsky is the most cited author with 589 citations. Brusilovsky is followed by RM. Felder with 222 citations, G.J. Hwang with 186 citations, BJ. Zimmerman with 166 citations, and A. Bandura with 163 citations.

4. How is the author-bibliometric coupling relationship network in the studies on "Adaptive Learning" in articles indexed in the Web of Sciences Core Collection (WoSCC) database?

"Bibliometric Coupling" Author- Bibliometric Coupling Network:

In the studies conducted on "adaptive learning" in the WoSCC database, a bibliometric coupling (authors) mapping was performed using VOSviewer. As a result, a total of 5,524 authors were identified, who had at least three publications, and 185 authors were included in the mapping. Among these authors, a subset of 180 authors was selected from 14 interconnected item sets, with a total of 7,692 connections between them. The network map, consisting of fourteen clusters, is as follows: the first cluster includes 52 authors, the second cluster includes 45 authors, each of the third and fourth clusters includes 17 authors, the fifth cluster includes 10 authors, the sixth cluster includes 9 authors, the seventh cluster includes 7 authors, the eighth cluster includes 6 authors, the ninth cluster includes 4 authors, and each of the tenth, eleventh, and twelfth clusters includes 3 authors. The thirteenth and fourteenth clusters consist of 2 authors each.
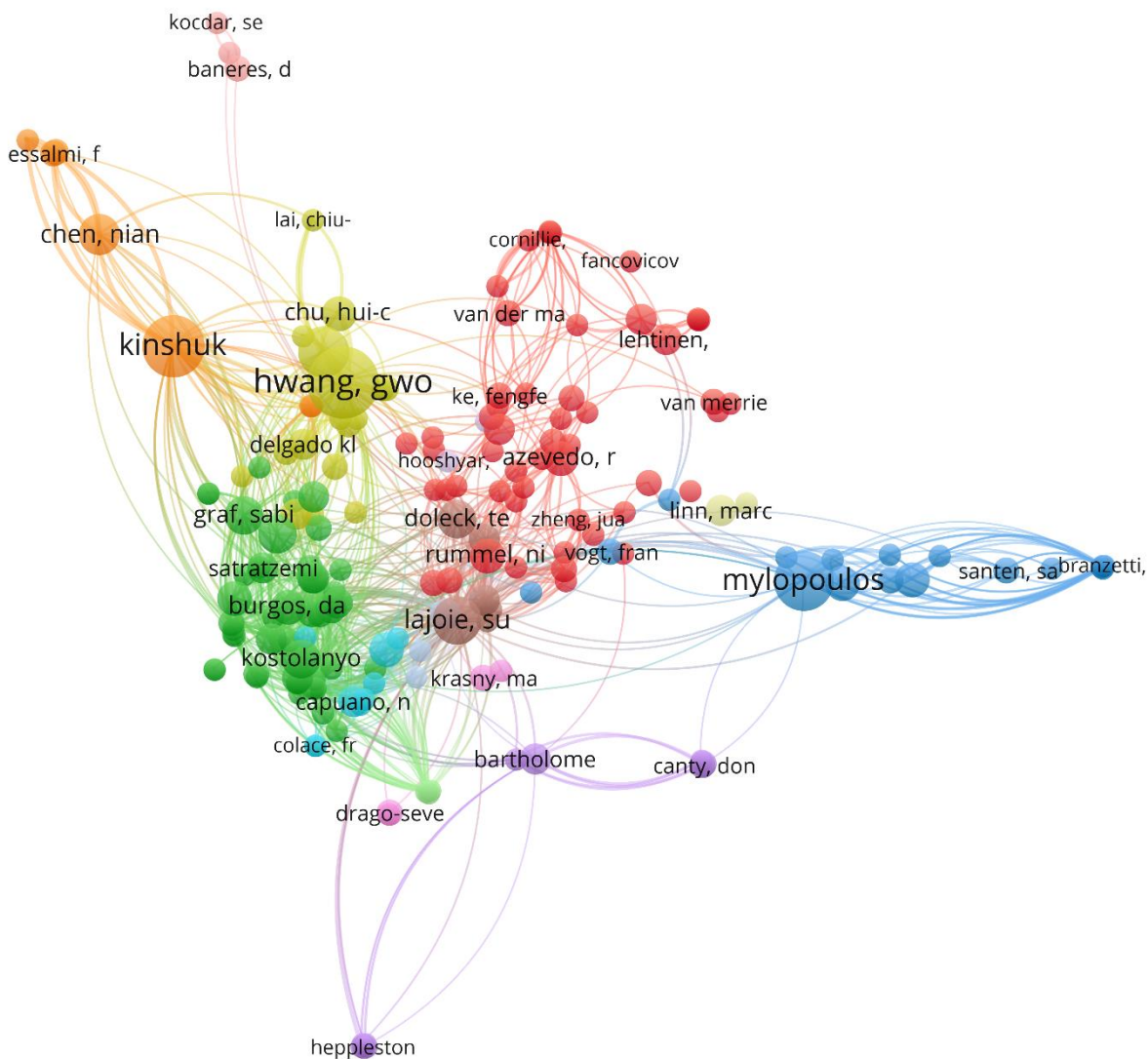

Figure 8. Author- Bibliometric Coupling Network

Figure 8 makes it evident that the authors S. Lajoie, G. J. Hwang, Kinshuk, C. Tsai, N. Chen, and M. Mylopoulos have a high level of bibliometric coupling connections in their studies.

C. Journal

1. What is the relationship between journal and citation in the studies on "Adaptive Learning" in the Web of Sciences Core Collection (WosCC) database?

"Citation Analysis" Journal-Citation Network:

In the studies conducted on "adaptive learning" in the WoSCC database, a Citation Analysis (sources) mapping was performed using VOSviewer. As a result, a total of 453 journals were identified, which had at least five publications and twenty citations, and 92 journals were included in the mapping. Among these journals, a subset of 83 journals was selected from 15 interconnected item sets, with a total of 390 connections between them. The network map, consisting of fifteen clusters, is as follows: the first cluster includes 15 journals, the second cluster includes 11 journals, the third cluster includes 8 journals, the fourth, fifth, and sixth clusters each include 6 journals, the seventh and eighth clusters each include 5 journals, the ninth and tenth clusters each include 4 journals, and the eleventh, twelfth, and thirteenth clusters each include 3 journals. The fourteenth and fifteenth clusters consist of 2 journals each.
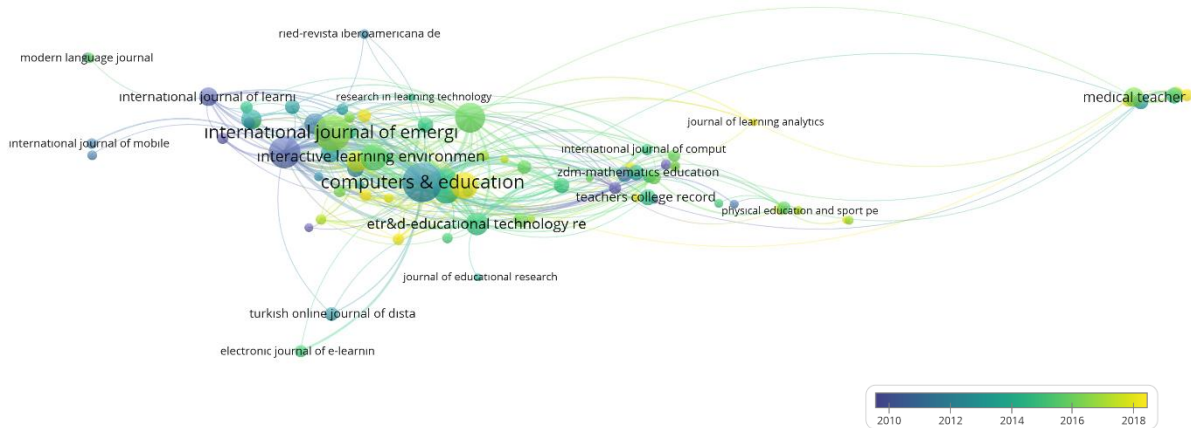

Figure 9. Journal Citation Network

In the Citation-Journal relationship network presented in Figure 9, as the citation relationships between the journals are examined, it can be observed that the journals in the fields of computer and instructional technologies, educational sciences, engineering and science education, and medical education are clustered together. In the citation network of journals, the strongest journal identified in the 11th cluster is *Computers & Education* with 107 publications and 4,538 citations. Considering the years, the journal with the strongest citation relationship after 2018 is *Education and Information Technologies* with 50 publications and 27 connections. When the citation relationships of journals are ranked based on connection strength, the top 20 journals with the highest number of connections are provided in Table 3.

Table 3 Ranking of Journals by Total Connection Strength in Citations

Source	Documents	Citations
Computers & Education	107	4538
Educational Technology & Society	70	1925
Interactive Learning Environments	48	390
Etr&D-Educational Technology Research and Development	36	1175
Ieee Transactions on Learning Technologies	61	1193
British Journal of Educational Technology	45	846
Journal of Computer-Assisted Learning	25	596
Education and Information Technologies	50	309
Computer Applications in Engineering Education	31	227
Ieee Transactions on Education	20	718
International Journal of Emerging Technologies in Learning	90	319
Educational Psychologist	10	943
Journal of Educational Computing Research	16	245
International Journal of Distance Education Technologies	31	154
International Journal of Technology Enhanced Learning	16	138
Academic Medicine	19	1441
Medical Education	17	475
Medical Teacher	27	404
Learning and Instruction	14	438
Journal of Computers in Education	9	75

2. What is the common citation relationship between the cited journals in the studies on "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

"Co-Citation Analysis" Cited Journals Network:

According to the Co-Citation Analysis (cited sources) conducted using VOSviewer on the articles indexed in the WoSCC database, a total of 30,632 studies related to "adaptive learning" were identified. To determine the most cited studies, 534 studies that received at least twenty citations were included in the analysis. These studies form seven interconnected clusters, with the first cluster consisting of 180 studies, the second cluster consisting of 136 studies, the third cluster consisting of 83 studies, the fourth cluster consisting of 69 studies, the fifth cluster consisting of 41 studies, the sixth cluster consisting of 22 studies, and the seventh cluster consisting of 3 journals.
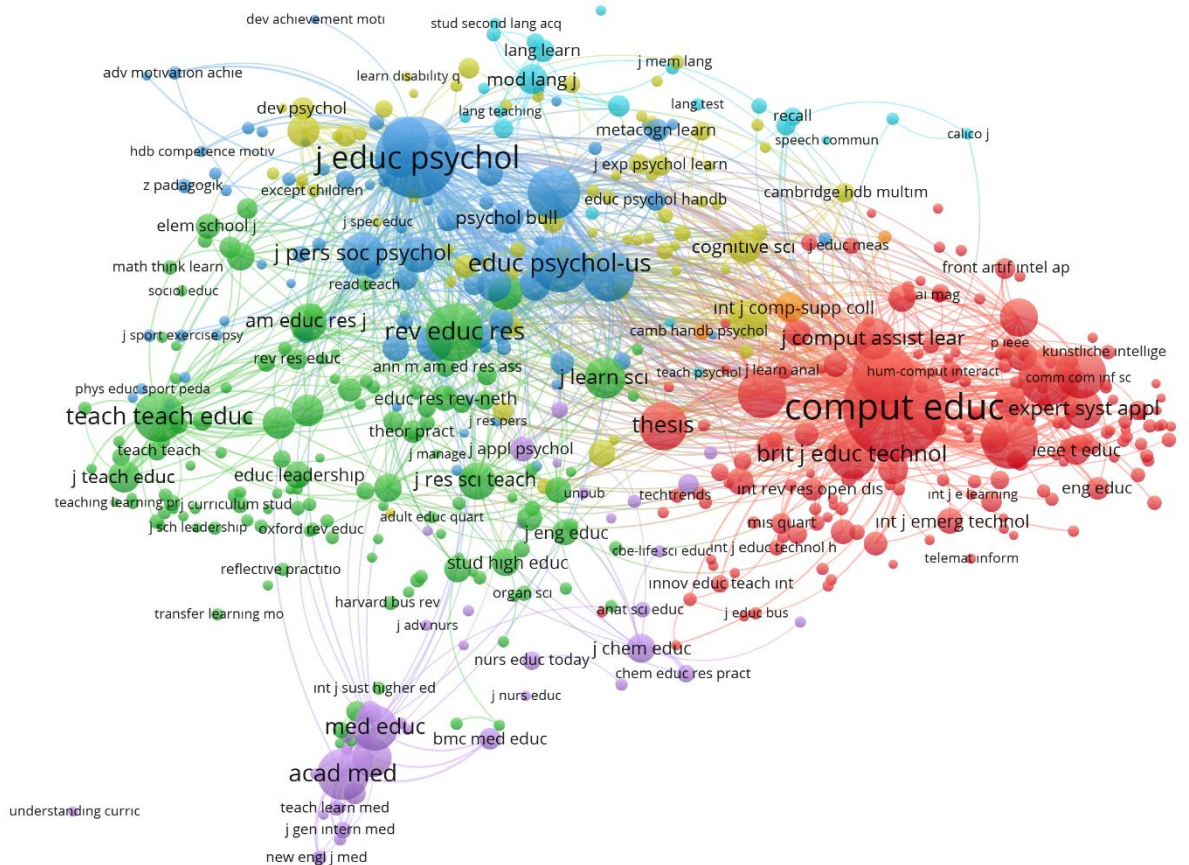

Figure 10. Cited Journals Network

In Figure 10, the first cluster visualized in red consists of journals in the field of computer education and educational technologies. The second cluster visualized in green consists of journals in educational sciences, curriculum, and educational research. The third cluster visualized in blue consists of journals in educational psychology. The fourth cluster visualized in yellow consists of journals in cognitive and behavioral sciences. The fifth cluster visualized in purple consists of journals in medical education/specialization. The sixth cluster visualized in turquoise consists of journals in foreign language education and language learning/teaching. The seventh cluster visualized in orange consists of journals on computer-supported learning and learning psychology. The first cluster contains *Computers & Education*, the second cluster includes *Review of Educational Research*, the third cluster includes *Journal of Educational Psychology*, the fourth cluster includes *Cognitive Science*, the fifth cluster includes *Academic Medicine*, the sixth cluster includes *The Modern Language Journal*, and the seventh cluster includes *International Journal of Computer-Supported Collaborative Learning*. These journals have the highest citation counts and total connection strengths within their respective clusters. Graph 3 presents the top 10 journals ranked in descending order based on total citation counts.
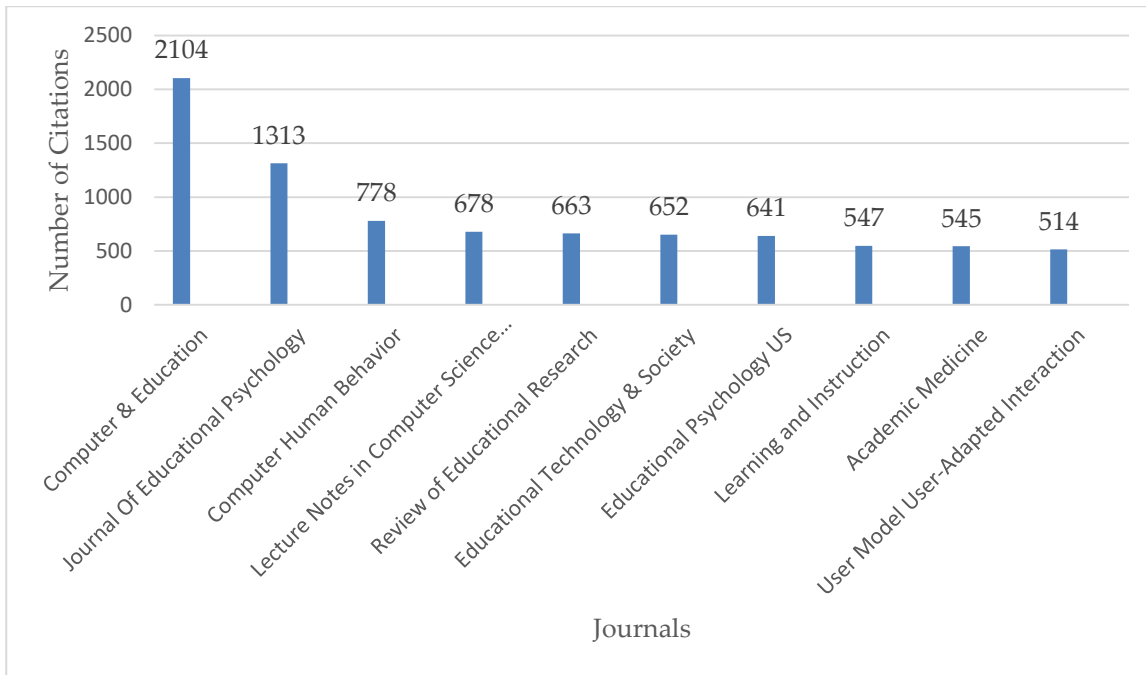
Graphic 3. Top 10 Most Cited Journals

When examining Graph 3, it can be observed that the journal with the highest co-citation relationship and the most cited publication on "adaptive learning" is *Computers & Education*. *Journal of Educational Psychology* and *Computers in Human Behavior* are the other highly cited journals. Looking at the first 10 journals shown, it can be seen that these journals have received over 500 citations.

3. In the articles indexed in the Web of Science Core Collection (WoSCC) database, what is the citation coupling network of journals about "Adaptive Learning"?

"Bibliometric Coupling" Journal-Bibliometric Coupling Network:

In the studies conducted on "adaptive learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database, a bibliometric coupling (sources) mapping was performed using VOSviewer. As a result, a total of 453 journals were identified, with at least five publications and twenty citations required for inclusion in the mapping. The mapping included 91 journals that met these criteria. The resulting network map consists of three clusters, with the first cluster comprising 48 journals, the second cluster comprising 27 journals, and the third cluster comprising 11 journals.
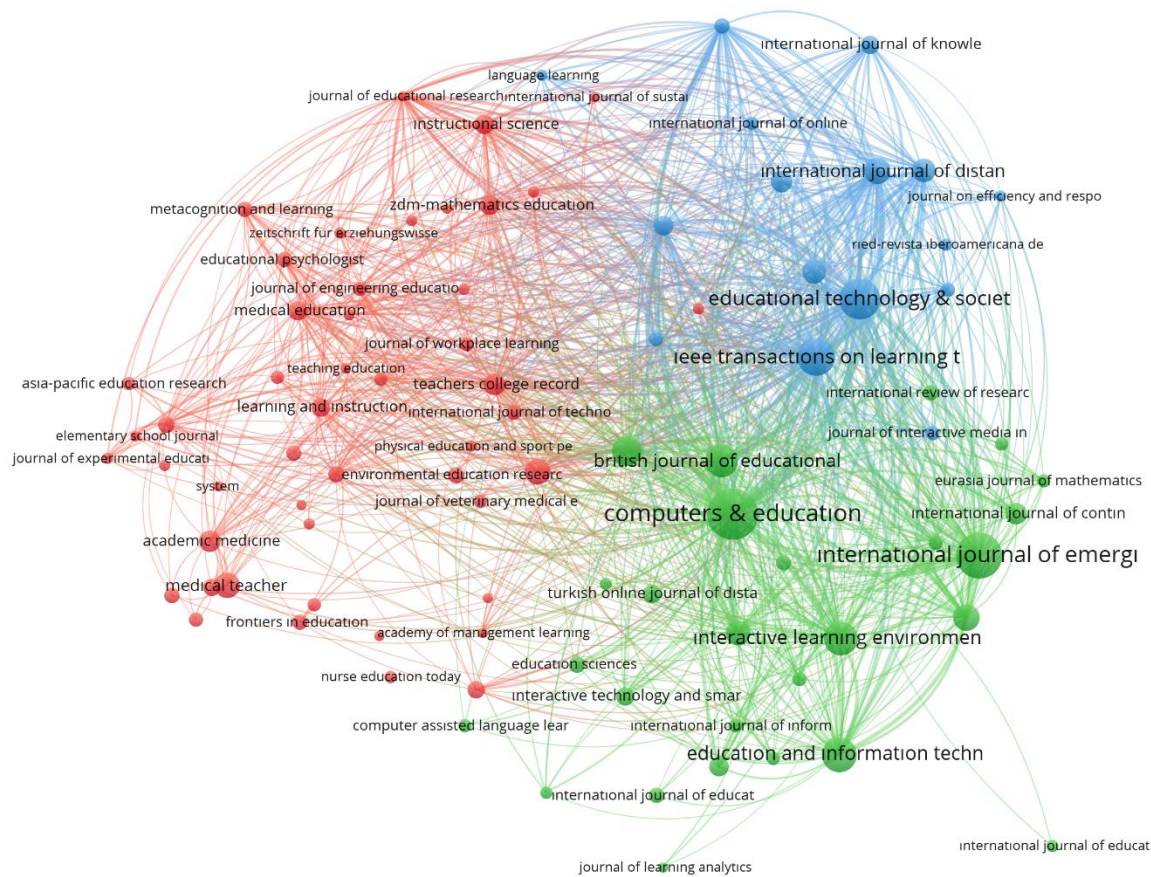
Figure 11. Journal Bibliometric Coupling Network

As the citation coupling network of journals presented in Figure 11 is examined, it can be observed that the journals in the second cluster (green) have stronger connections with each other. For example, journals such as *Computers & Education, Education & Information Technologies, Interactive Learning Environments, International Journal of Emerging Technologies in Learning, Educational Technology Research and Development*, and *British Journal of Educational Technology* exhibit such strong connections.

D. Country

1. In the articles indexed in the Web of Science Core Collection (WoSCC) database, what are the countries and collaborations involved in studies related to "Adaptive Learning"?

"Co-authorship Analysis" Country Collaboration Network:

In the studies conducted on "adaptive learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database, a Co-Authorship Analysis (countries) mapping was performed using VOSviewer. As a result, a total of 95 countries were identified, and 43 countries that had at least ten publications and twenty citations were included in the mapping. A set of 40 countries was selected as interconnected elements, with 227 connections between them. The resulting network map consists of seven clusters, with the first cluster comprising 14 countries, the second cluster comprising 8 countries, the third cluster comprising 5 countries, the fourth cluster comprising 4 countries, the fifth cluster comprising 4 countries, the sixth cluster comprising 4 countries, and the seventh cluster comprising 1 country.
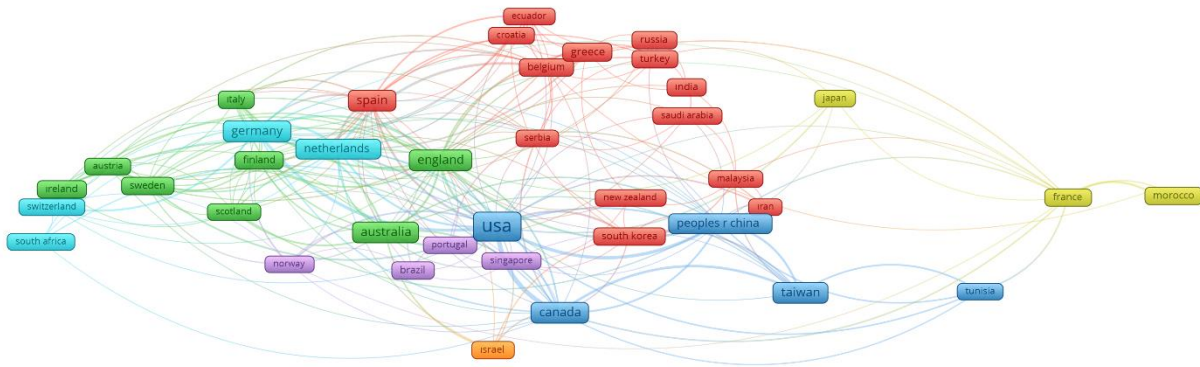
Figure 12. Country Collaboration Network

In the relationship network depicted in Figure 12, the United States is observed to have the highest number of connections with 29 networks. Additionally, the United States has 574 publications related to "Adaptive Learning". Turkey, on the other hand, has 40 publications, 393 citations, and is connected to 9 networks. In the global ranking of countries conducting research in the field of "Adaptive Learning", Turkey ranks 16th in terms of citation count and 28th in terms of total link strength.

2. What is the citation relationship according to countries in the studies on "Adaptive Learning" in the Web of Sciences Core Collection (WosCC) database?

"Citation Analysis" Country- Citation Network:

In the Citation Analysis (countries) mapping conducted through VOSviewer, a total of 95 countries have been identified in the articles related to "adaptive learning" indexed in the WoSCC database. Among these, 43 countries with a minimum of ten publications and twenty citations have been included in the mapping. As a result of analyzing their citation relationships, these 43 countries form a network consisting of 8 clusters, with a total of 398 connections between them. The first cluster consists of 11 countries, the second cluster consists of 9 countries, the third cluster consists of 7 countries, the fourth cluster consists of 6 countries, the fifth cluster consists of 4 countries, the sixth cluster consists of 2 countries, the seventh cluster consists of 2 countries, and the eighth cluster consists of 2 countries.
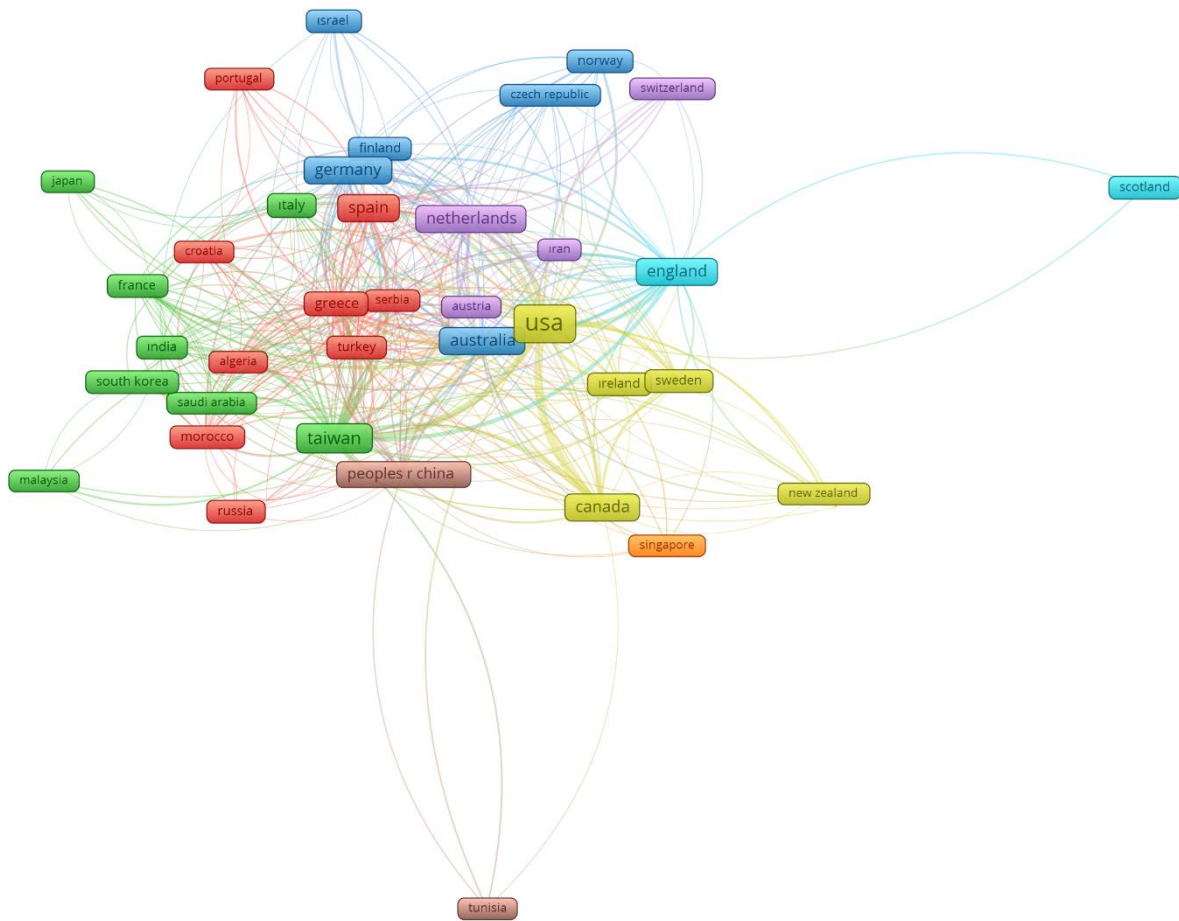
Figure 13. Country Citation Network

In the Citation-Country relationship network depicted in Figure 13, as the countries receiving the highest number of citations are examined, the United States (with 11,085 citations and 574 publications) emerges as the first country with the highest link strength. It is followed by Taiwan with 3,994 citations and 145 publications, and Canada with 2,437 citations and 134 publications. Turkey ranks 9th in terms of total citation link strength, with 40 publications and 393 citations. Additionally, it can be observed that the countries in Asia and Africa generally occupy lower positions in the citation relationship network.

3. In studies related to "Adaptive Learning" indexed in the Web of Science Core Collection (WoSCC) database, what is the bibliometric coupling relationship network among countries?
"Bibliometric Coupling" Country- Bibliometric Coupling Network:

In the studies related to "adaptive learning" indexed in the WoSCC database, a bibliometric coupling (countries) mapping was conducted using VOSviewer. As a result, a total of 95 countries were identified, and 43 countries were included in the mapping that had at least ten publications and twenty citations. From these countries, a set of four clusters was selected, comprising a total of 43 countries, with a total of 901 connections among them.
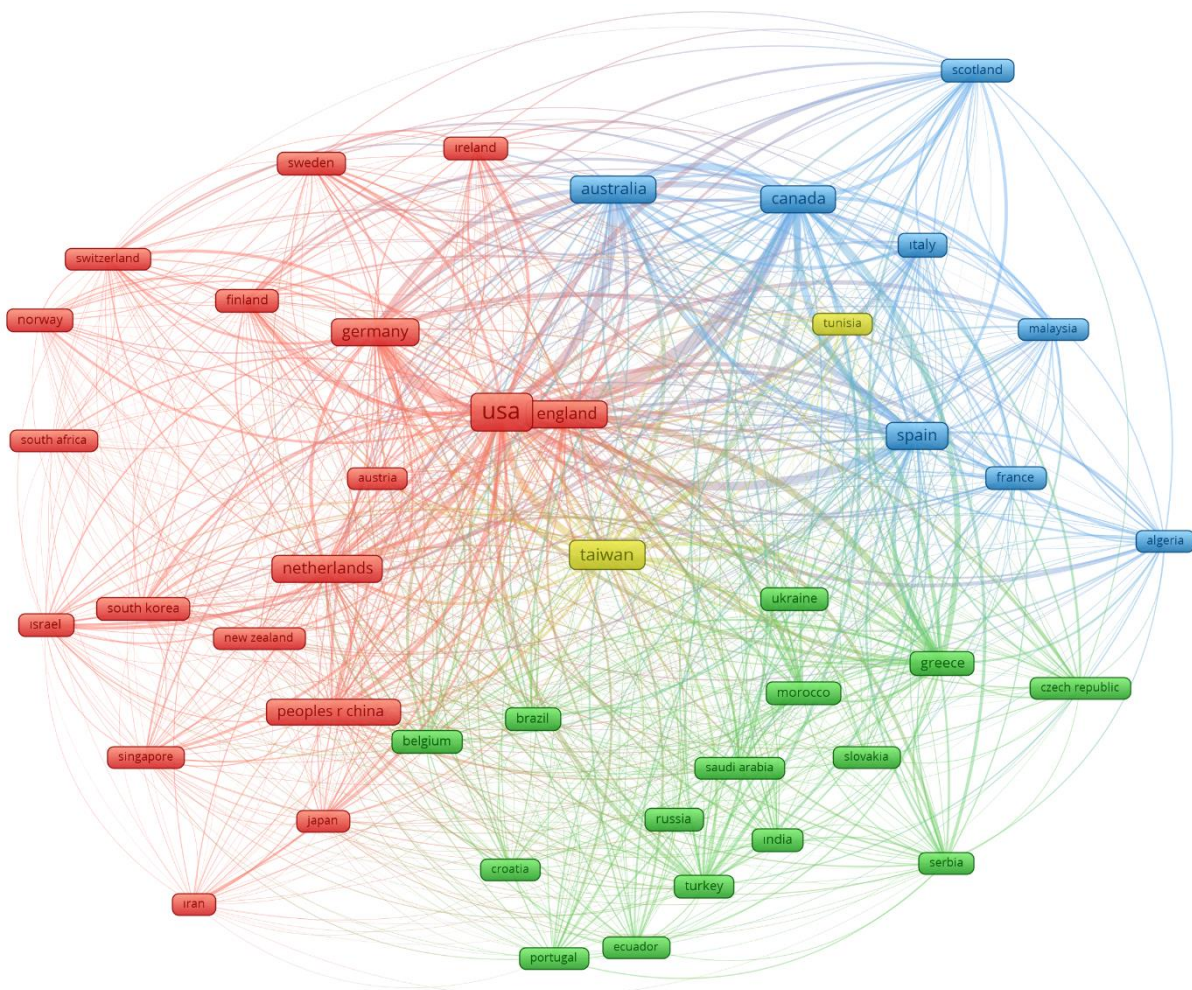
Figure 14. Country Bibliometric Coupling Network

In Figure 14, the bibliometric coupling relationship network of countries shows that the United States has the strongest network of relationships. It has connections both within its cluster and with the countries in other clusters. The cluster with the largest number of countries, consisting of 18 countries, is identified as Cluster 1 (red). Taiwan and Tunisia (yellow) show distinctiveness in the bibliometric coupling relationship network and form their terms. Turkey, on the other hand, is part of Cluster 2 (green).

E. Keyword

What are the common keywords in the studies conducted on "Adaptive Learning" in the articles indexed in the Web of Science Core Collection (WoSCC) database?

"Co-word Analysis"

In the VOSviewer co-word analysis mapping of the articles related to "adaptive learning" in the WoSCC database, a total of 5,492 keywords were identified. To examine the frequency of these keywords, 107 keywords that were associated at least ten times were included in the mapping. As a result, 847 connections were found among these selected 107 keywords, forming a network of interconnected elements. The network is divided into 8 clusters based on the relationships between keywords. The first cluster consists of 24 keywords, the second cluster consists of 17 keywords, the third cluster consists of 16 keywords, the fourth cluster consists of 14 keywords, the fifth cluster consists of 13 keywords, the sixth cluster consists of 10 keywords, the seventh cluster consists of 8 keywords, and the eight cluster consists of 5 keywords.
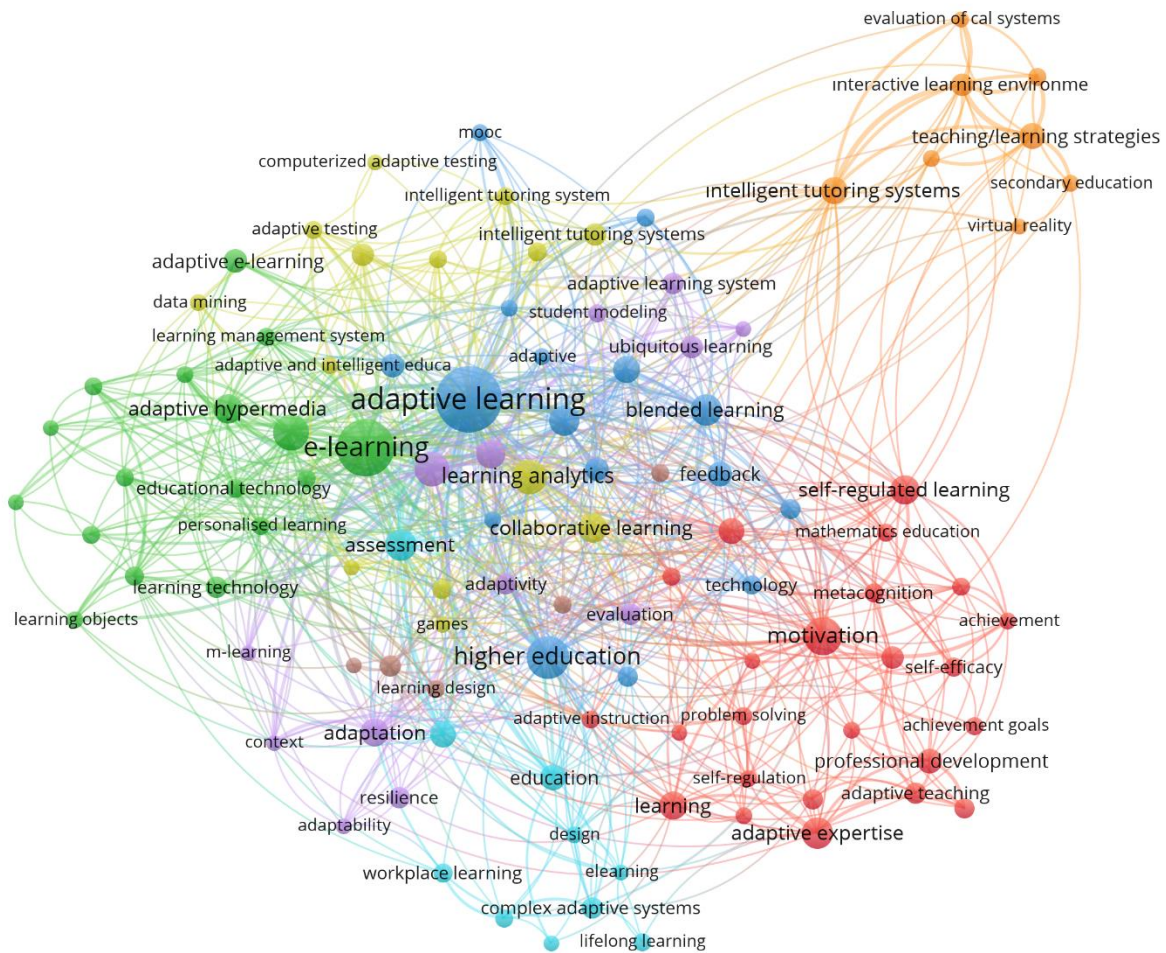
Figure 15. Common-Keyword Network

When examining Figure 15, it can be observed that the most frequently associated keywords with "adaptive learning" are e-learning, higher education, and motivation. When analyzed over the years, particularly in recent years (2018-...), it is evident that studies related to "adaptive learning" are associated with keywords such as higher education, learning analytics, blended learning, online learning, artificial intelligence, flipped classroom, machine learning, educational technology, intelligent tutoring system, mathematics education, MOOC, games, and Covid-19. Despite being a newcomer to the literature, "Covid-19" has managed to establish itself among the conducted studies.

RESULTS and DISCUSSION

The research aimed to reveal the trends in research articles focusing on adaptive learning in the Web of Science Core Collection (WoSCC) database. For this purpose, scanning methods and bibliometric analysis techniques were used. The findings obtained from the research were reported based on publications, authors, journals, countries, and keywords. Analyzing the publications, it was found that the publication with the most connections is Akbulut (2012), the publication with the most citations is Hwang (2008), and the most cited publication is Felder (1988). The findings obtained through the citation analysis of the publications also indicate that the created clusters are related to fields such as learning, engineering and computer science, psychology, and learning psychology. When the bibliometric couplings of the publications were examined, it was found that the publication by Brinton (2015) has the highest total link strength. Looking at the results related to the publications, it is expected that Akbulut & Cardak's (2012) article published in *Computer & Education*, which examines 70 studies on adaptive educational hypermedia in terms of learning styles and conducts a content analysis, and particularly gathers all the studies published on the topic in a single study and publishes it in an influential journal in the field, has the highest number of connections. In their studies, it is observed that Hwang, Tsai & Yang (2008) examine criteria and strategies related to ubiquitous learning, and Felder & Silverman (1988) examine engineering education in terms of learning and teaching styles. Brinton and colleagues (2015), on the other hand, researched the design, implementation, and pre-evaluation of the Mobile Integrated and Individualized Course (MIIC), an adaptive

learning system. The findings obtained and the studies conducted in the field of engineering/computer science support Xie et al.'s (2019) study, which identified engineering/computer science as the most popular learning content in research on adaptive learning.

In the research, based on author analysis, it is observed that Daniel Burgos has the strongest network and engages in the largest number of collaborations, Gwo-Jen Hwang forms the largest number of connections, and Peter Brusilovsky is the most cited/referenced author. Additionally, it was found that S. Lajoie, GJ. Hwang, Kinshuk, C. Tsai, N. Chen, and M. Mylopoulos have high bibliometric coupling connections in their studies. Burgos, who has researched topics such as educational technology, educational innovation, e-learning, open education, and learning analytics, is the most collaborative author due to his choice to study variables that are associated with adaptive learning. Burgos, Tattersall & Koper's (2006) studies focusing on adaptive e-learning strategies within the context of IMS Learning Design exemplify this. Similarly, Hwang, who studies topics such as mobile learning, digital game-based learning, artificial intelligence in education, and flipped learning along with his colleagues, developed and tested an adaptive learning system in a joint publication titled "Development of an adaptive learning system with two sources of personalization information" (Tseng, Chu, Hwang & Tsai, 2008). Similarly, Brusilovsky studies topics including user modeling, personalization, artificial intelligence in education, learning technologies, and recommender systems. Brusilovsky's study titled "Adaptive Hypermedia", published in 2001 holds a significant position among the most cited publications after Felder & Silverman (1988) in the literature.

In the research, based on journal analysis, it is observed that journals cluster in the fields of computer and instructional technologies, educational sciences, engineering and science education, and medical education in terms of citation relationships. The journal with the strongest citation relationship in the network is *Computers & Education*. When the years are considered, *Education and Information Technologies* is the journal with the strongest citation relationship after 2018. Additionally, *Computers & Education* is the journal with the most shared citation relationships and the most cited journal on "adaptive learning". *Journal of Educational Psychology* and *Computers in Human Behavior* are the other highly cited journals. Looking at the results related to journals, *Computers & Education* stands out as the prominent journal on "adaptive learning" The journal is a strong, highly cited, and popular journal in the field of "adaptive learning" due to its focus on research papers on the pedagogical uses of digital technology, coverage of topics such as the implementation of software and/or hardware, the user/system interface, usability issues and evaluations of the user experience, implications for learning and teaching, publishing 16 issues per year, having a journal impact factor of 11.182 and a Journal Citation Indicator of 3.75 as of 2021, and being indexed in SSCI Q1.

Based on country analysis, it is observed that the United States is the country with the strongest network connections. In the global ranking of countries researching "Adaptive Learning," Turkey ranks 16th based on citation count and 28th based on total link strength. When looking at the countries receiving the most citations in the citation-country network, the countries with the highest link strength are the US, Taiwan, and Canada. Turkey ranks 9th in terms of total citation link strength. Additionally, it can be observed that the countries from Asia and Africa generally rank lower in the citation relationship network.

When the Co-Occurring Keyword Network is examined, it is observed that the most frequent keywords associated with "adaptive learning" are e-learning, higher education, and motivation. Additionally, it is evident that studies related to "adaptive learning" as of 2018 are associated with keywords such as higher education, learning analytics, blended learning, online learning, artificial intelligence, flipped classroom, machine learning, educational technology, intelligent tutoring system, mathematics education, MOOC, games, and Covid-19. Despite being a recent addition to the literature, Covid-19 has managed to establish its presence within the conducted studies. Based on the keywords used in the studies, it can be interpreted that the body of research tends to focus more on higher education, e-learning environments, and investigations of the variable of motivation. The finding that 46% of the studies on adaptive learning, as reported by Xie et al. (2019), were conducted with higher education students, helps explain the prominence of the keyword "higher education." Furthermore, it is noted that topics such as learning analytics, artificial intelligence, machine learning, and intelligent tutoring system have gained increasing attention in recent years, as highlighted by Somyürek (2015). In conclusion, it is evident that the research on adaptive learning primarily focuses on creating adaptable environments that provide more usable and personalized learning experiences.

The research findings indicate that the trends regarding adaptive learning are evolving, and different variables are gaining importance in the context of adaptive learning. Therefore, it is crucial 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.

Declarations

Conflict of Interest

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Research and Publication Ethics Statement

We as the authors consciously assure that for the manuscript "The Trends in Adaptive Learning Research: A Bibliometric Analysis Study" the following is fulfilled:

- This material is the authors' own original work, which has not been previously published elsewhere.
- The paper reflects the authors' own research and analysis in a truthful and complete manner.
- The results are appropriately placed in the context of prior and existing research.
- All sources used are properly disclosed.

Contribution Rates of Authors to the Article

1st author contributed 20%, 2nd author 20%, 3rd author 20%, 4th author 20% and 5th author 20%

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