

Bibliometric Analysis on Recent Topics in ILS Research

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Research Article

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Bibliometric Analysis on Recent Topics in ILS Research

ABSTRACT

This article presents a bibliometric analysis of recent topics in ILS (Individual Learning Styles) research. The methodology employed was based on a systematic review of documents and scientific publications related to the study object from 2004 to the present utilizing the Scopus database and the 'bibliometrix' package in the R programming language. Several decision steps were followed to ensure the reliability and validity of the analysis. The findings allowed for the identification of the most cited journals, the most prominent authors, and the most common affiliations among the authors of the analyzed documents. Additionally, different models of learning style preferences and their impact on the teaching process were explored. The findings contribute significantly to understanding the dynamics of research in the studied discipline. Regarding the most cited journals, "Computers & Education" was found to be the leading journal in terms of the total number of citations, followed by "Educational Research Review" and "Learning and Instruction". As for the most prominent authors, several relevant names were identified, such as David Kolb, Richard Felder, and Peter Honey. Regarding the most common affiliations among the authors, it was found that several Spanish universities lead this list. On the other hand, this study explored different learning style models and their impact on the educational process. It was found that there is a wide variety of theoretical models on learning style, but there is no clear consensus on which model is best to apply in an educational context. However, the importance of considering students' learning styles to adapt the educational process to their individual needs was highlighted. In conclusion, this bibliometric analysis provides an overview of the current state of ILS research and can be useful for researchers, educators, and professionals interested in this field. The obtained results can also be used to identify current trends in ILS research and to guide future investigations in this area.

Keywords: Learning styles, Bibliometric analysis, Educational research, Felder-Silverman method, Educational technology, Personalized learning.

1. INTRODUCTION

Learning styles are a set of individual needs, objectives, and preferences that affect students' learning processes (Ciloglugil & Inceoglu, 2018; Pashler et al., 2008). Over 70 instruments have been used to detect learning styles for assessment among students (Hall & Moseley, 2005). Several learning style models have been developed to model individual differences in the classroom. According to Diago et al. (2018), the learning style preference detection instruments that are most prevalent in various search engines are the VAK/VARK questionnaires (Google Scholar in any language), CHAEA (Google Scholar in Spanish), and ILS (Felder & Soloman, 1997) (Web of Science and ScienceDirect). Additionally, when only Spanish works are considered, the most relevant questionnaire is CHAEA (Spanish adaptation of Honey & Mumford's LSQ, 1982), followed by VAK/VARK. This analysis was performed based on an exhaustive bibliographic search in different search engines and a bibliometric analysis during the period from May 21, 2015, to April 30, 2017 (Diago et al., 2021, pp. 96, 103, 104, and 111).

The Kolb learning style model is based on the "Experiential Learning Theory," which describes learning as a cyclical process involving four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. According to this model, students can be classified into four types based on their preference for these stages: "Accommodators," "Assimilators," "Convergers," and "Divergers" (Kolb, 1982).

Another model, such as the Honey-Mumford model, is also divided into four subclasses: "Activist" (corresponding to Kolb's "Accommodators"), "Theorist" (corresponding to Kolb's "Assimilators"), "Pragmatist" (corresponding to Kolb's "Convergers"), and "Reflector" (corresponding to Kolb's "Divergers") (Honey & Mumford, 1984).

Finally, the Felder-Silverman model (FSLSM) was developed by Richard Felder and Linda Silverman in the 1980s to evaluate and understand learning styles. This model is based on four dimensions (preprocessing, perception, input, and understanding) and eight student categories (active, reflective, sensing, intuitive, visual, verbal, sequential, and global) considered relevant for effective student learning (Felder & Silverman, 1988; Kolekar et al., 2019).

According to Felder and Soloman (2004), in the educational context, the learning style refers to a particular set of behaviors related to how students perceive, interact with, and respond to the learning environment. These behaviors are divided into four dimensions: active vs. reflective, sensing vs. intuitive, visual vs. verbal, and sequential vs. global.

Active learners prefer to explore or test information, while reflective learners are more introspective. Sensing learners prefer facts, data, and experimentation, while intuitive learners prefer theories, principles, and innovation. Visual learners perceive information more effectively through images and graphics, while verbal learners prefer written or spoken words. Finally, sequential learners progress through linear and ordered steps, while global learners often learn holistically in large steps (Felder & Soloman, 2004).

Felder and Silverman developed the Felder-Soloman Learning Style Survey, which is based on four dimensions (perception, reception, understanding, and processing) and consists of 44 items with dichotomous Thurstone-type response scales (Ramírez & Márquez, 2021). The survey has been empirically validated in various contexts and is widely used in educational settings (Coffield et al., 2004; Diago, 2022a).

The Felder-Silverman learning style model is relevant in differentiated learning as teachers need to be aware of students' learning styles in the classroom to adapt to specific learning preferences. Additionally, the Felder-Silverman Learning Style Index (ILS), initially designed to evaluate the learning styles of engineering students, is a useful tool for assessing individual students' learning styles (Mirza et al., 2022).

The results of the Felder-Soloman Learning Style Survey can be used by educators to design instructional materials and activities that align with students' learning styles (Cuetos et al., 2021; Felder & Soloman, 1991). It is important to note that the validity of the ILS exam is relevant for secondary education students as learning styles can influence how they process and retain information, which in turn can affect their academic performance (Mirza et al., 2022).

Various studies have demonstrated the validity and reliability of the Felder-Silverman Learning Style Survey for identifying students' learning styles (Diago et al., 2022b; Felder & Silverman, 1988; Mirza et al., 2022).

Learning styles have been evaluated in different areas such as health sciences (Zoghi et al., 2010), medicine (Bhagat et al., 2015), nursing (Andreou et al., 2014), and educational stages like secondary education (Diago et al., 2022b), highlighting the importance of adapting teaching strategies and electronic media to individual students' learning styles to improve their academic performance (Mirza et al., 2022).

Graf and Kinshuk (2007) proposed a course adaptability system based on students' learning styles. They evaluated the learning style using the Felder-Silverman Learning Style Model (FSLSM) in the Moodle online learning system through an additional installation. On the other hand, Liyanage et al. (2014) proposed a framework for an adaptive Learning Management System (LMS) that can change course content based on the student's individual learning style. They used a questionnaire and rule-based method to understand student activity within the LMS and the FSLSM as the learning style model.

Kolekar et al. (2017) pointed out that the main requirement of the e-learning system is to provide a personalized interface with content adapted to students' learning styles, which is achieved by knowing their learning styles. In

their study, they captured students' learning behavior on the e-learning portal through web log mining and assigned learning styles to the Felder-Silverman model categories (FSLSM).

Bibliometrics is a discipline that uses quantitative analysis to evaluate information in scientific and technical publications to measure the production, dissemination, and use of scientific information through the study of relationships between authors, journals, topics, and bibliographic citations (Hicks et al., 2015).

In educational research, bibliometrics is useful for analyzing trends, evaluating research quality, measuring the impact of researchers and their publications, and identifying potential collaborations and research networking opportunities (Cronin & Sugimoto, 2014).

Bibliometrics is widely used in various fields of knowledge, and new indicators such as altmetrics have been introduced to measure the impact of scientific activity.

Bibliometrix software is a useful tool for conducting bibliometric analyses and has a highly relevant reference bibliography (Aria & Cuccurullo, 2017). Bibliometric studies have been conducted in specific scientific journals (Gómez et al., 2019; López et al., 2019; Prieto & Segado, 2019), and bibliometrics is a useful tool for analyzing research in education and other fields of knowledge (Alhuay et al., 2022).

In educational research, bibliometrics is useful for analyzing trends, evaluating research quality, measuring the impact of researchers and their publications, and identifying potential collaborations and research networking opportunities (Cronin & Sugimoto, 2014).

There are two main types of bibliometric analyses. The first uses descriptive statistics to analyze the overall size of the corpus, the annual volume of publications, and their geographical distribution. The second type of data analysis focuses on "scientific mapping" (Van Eck & Waltman, 2011, 2017; Zupic & Cater, 2015). This method uses analytical tools such as citation analysis, co-citation analysis, and keyword analysis to identify the fundamental characteristics of a body of knowledge.

Co-citation analysis (Acedo et al., 2006) helps explore intellectual connections between influential articles in a discipline and map the intellectual structure of the discipline (Calabretta et al., 2011; Culnan, 1987; White & Griffith, 1981; White & McCain, 1998).

In the co-citation network of sources, documents, and authors, nodes represent scientific documents, and edges represent the frequency with which two documents are cited together in other works (Yayla, 2023). Ultimately, it focuses on the technique of evaluating the influence and relevance of a specific article or author based on the number of times the article or author has been cited in other academic works. This technique is used to analyze the cognitive structure of a specific scientific field. The identification of study groups arises when a significant number of authors jointly cite a coherent group of articles. Regarding the evaluation of the influence and relevance of a scientific journal or information source, a similar technique is used based on the number of times articles published in that journal or source have been cited in other academic works (Al-Zaman, 2021; Xia et al., 2022).

Bibliometric analysis can be applied to identify research trends, relationships between documents, authors, sources, and countries in various fields of study, particularly focusing on cluster analysis (Lin et al., 2023). Creative cluster research (CCR) can also be explored to investigate different aspects (Casadei et al., 2023).

The use of "Keywords Plus" in bibliometric analyses improves the search and analysis of scientific documents by expanding keywords with supplementary terms from the titles of cited articles. This facilitates the retrieval of relevant documents, identification of trends and emerging topics, construction of keyword networks, and discovery of interdisciplinary connections, thereby enriching the study and exploration of specific research fields (Al-Moraissi et al., 2023; Araújo et al., 2023; Cantos-Mateos et al., 2012; Tam et al., 2023).

The results obtained in our study will contribute significantly to understanding the dynamics of learning styles research and can be useful for researchers, educators, and professionals interested in this field. The findings can

also be used to identify current trends in learning styles research and guide future investigations in this area. Similarly, this study can provide insights into how different learning style models can be applied in an educational context to improve teaching effectiveness and student outcomes.

2. OBJECTIVES

The first objective of this study is to conduct a bibliometric analysis of recent research on learning styles with a particular focus on the Felder-Silverman method. The study aims to identify the most cited journals, prominent authors, and common affiliations among the authors of the analyzed documents. Additionally, the study seeks to explore different learning style models and their impact on the educational process. Several decision steps will be followed to ensure the reliability and validity of the analysis.

The second objective is to analyze the academic cooperation existing between researchers and scholars from different countries and their interaction and significant contributions to the research.

The results obtained in this study will contribute significantly to understanding the dynamics of learning styles research and can be useful for researchers, educators, and professionals interested in this field. The findings can also be used to identify current trends in learning styles research and guide future investigations in this area. Additionally, this study can provide information on how different learning style models can be applied in an educational context to improve teaching effectiveness and student outcomes.

3. METHODOLOGY

To achieve these objectives, a systematic review and bibliometric analysis of documents and scientific publications related to the study object from 2004 to the present using the Scopus database and the 'bibliometrix' package in the R programming language will be conducted. In this study, an exhaustive review of documents and scientific publications related to the study object from 2004 to the present using the Scopus database and the 'bibliometrix' package in the R programming language was conducted (Aria & Cuccurullo, 2017). A systematic methodology was followed in several decision steps to ensure the reliability and validity of the analysis (Benavides et al., 2022; David & Han, 2004; Newbert, 2007; Ribes et al., 2018; Sanahuja & Ribes, 2015).

To ensure the reliability and validity of this analysis on learning styles, a rigorous methodology was followed. This includes the use of validated and recognized instruments such as the Felder-Soloman Learning Style Survey (Diago et al., 2022b; Felder & Silverman, 1988; Mirza et al., 2022) and the systematic and transparent application of bibliometric methods using specialized tools such as Bibliometrix. A systematic methodology was followed in several decision steps to ensure the reliability and validity of the analysis (Benavides et al., 2022; David & Han, 2004; Newbert, 2007; Ribes et al., 2018; Sanahuja & Ribes, 2015). On the other hand, the quality of the included studies was evaluated using citation and co-citation analyses to identify influential works and ensure a wide diversity of sources and perspectives to avoid bias. Meticulous documentation of the research process also promotes transparency and allows for replicability, while critical analysis and contextualization of the data within the field of education ensure the validity of the conclusions.

The research process began with the formulation of questions that would guide the study (Alcalá et al., 2021). These questions focused on identifying sources, authors, affiliations, and countries conducting research on the Index of Learning Styles/Felder-Silverman and Felder-Solomon, as well as analyzing keywords and main thematic lines related to the topic.

To achieve these objectives, keywords in English were selected to maximize search results. The keywords used are: ("Felder S*" OR "Felder-S*") AND (ils OR "learning styles" OR "learning styles")

The next step involved reviewing and reading the titles and abstracts to ensure they all belonged to our study object and avoid possible duplicates.

Subsequently, searches were conducted in the international Scopus database. Specific search criteria were defined, limiting the review of studies and articles to a time frame from 2004 to 2023.

To perform a quantitative analysis, bibliometric analysis software (Bibliometrix) was used. This tool was used to design a bibliometric map that visualized the systematic and conceptual structure of the research field.

For a quantitative analysis of the research field, bibliometric indicators and specialized software, specifically Bibliometrix, were applied to design bibliometric maps that visualized the semantic and conceptual structure of the field (Büyükkidik, 2022; Logatti & Nazareth, 2022). The bibliometric analysis followed the three stages proposed by Aria and Cuccurullo (2017), beginning with the descriptive analysis of the document's bibliographic attributes such as publication year, author names, keywords, and other basic data. Bradford's Law (Pinto et al., 2013; Silva et al., 2023; Wadasinghe, 2020) was used to find the most relevant sources on a specific topic. Lotka's Law was also used to analyze the distribution of scientific productivity of authors in the field of study. According to this law, a few authors produce the majority of works, while most authors publish a single document. This allows us to identify key authors and leading institutions significantly contributing to the body of knowledge on the topic in question (Manthiramoorthi et al., 2020; Naheem Mr, 2019; Silva et al., 2023).

The second stage, called "Academic Cooperation," identified relationships between documents through received citations (Caldarelli, 2021; Li & Man, 2022). Co-citation analysis was performed to explore how documents are interrelated and which are considered fundamental within a specific field of study. This analysis allows identifying the most influential works and how they contribute to forming scientific communities around specific topics. By examining co-citations, it is possible to detect thematic cores that have guided research in the area, as well as emerging trends and transitions in theoretical or methodological focus over time (Ahamed, 2022; Hota et al., 2020).

The cluster analysis was conducted to identify groupings of documents sharing similar themes or approaches, revealing the most cohesive and collaborative subareas of research within the field. This approach helps visualize the conceptual structure of the study area, highlighting intrinsic relationships between different lines of research and how they have developed and diversified over time. This cluster analysis not only facilitates understanding the internal dynamics of the study area but also guides emerging topics and potential future research directions, promoting new collaborations and interdisciplinary approaches (Lin et al., 2023; Torres-Pruñonosa et al., 2021).

In the third stage, a keyword and critical point analysis was conducted to understand the semantic structure of the research field (Yang et al., 2023; L. Zhang et al., 2022; X. Zhang & Ma, 2023). Following the same methodology, two additional stages were added: research trajectory and future evaluation proposal to obtain a complete and updated view of the research field in question (Kozhakhmet et al., 2023; Salim et al., 2023).

In terms of thematic development analysis to observe how the collection of topics has evolved over time and through subphases (Kristia et al., 2023; Mishra et al., 2020; Verma & Ghosh, 2022), we divided the total study period (2004-2023) into three time segments: 2004-2016, 2017-2019, and 2020-2023.

Through historiography, we can understand which works have been most frequently cited by other works over time (annually) using local citation score (LCS) and global citation score (GCS) (Santonastaso et al., 2023).

Finally, multiple correspondence analysis (MCA) will be performed to detect and elucidate underlying structures in nominal category data (Santonastaso et al., 2023; Utomo & Cham, 2023).

4. RESULTS OF THE BIBLIOMETRIC ANALYSIS

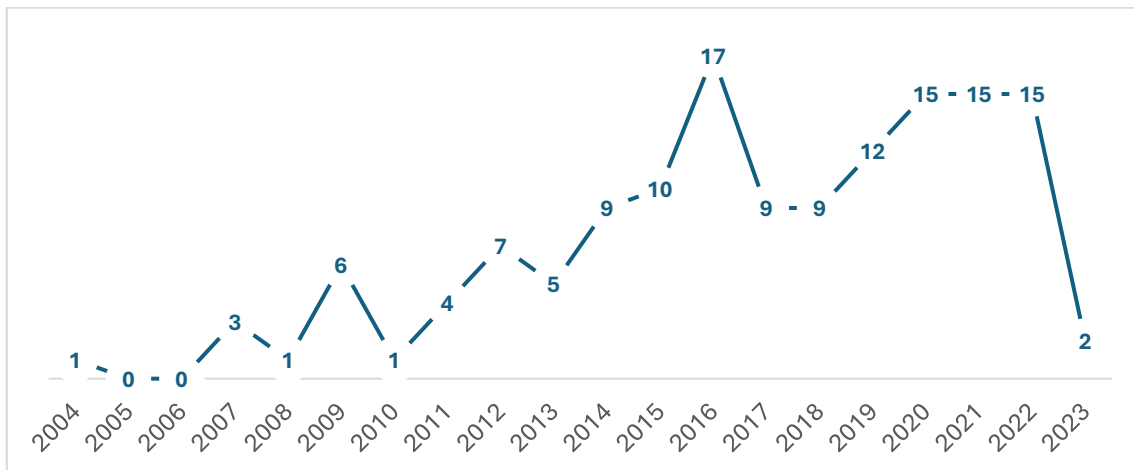
4.1. Descriptive Analysis of Document Bibliographic Attributes

The number of articles is an important indicator for measuring the development of a topic in a specific research field. In other words, the number of articles published on a topic can be a useful measure to evaluate its relevance and progress in the scientific community. For our research, this corresponds to a total of 141 articles published in 101 journals and 357 authors. The result was as follows: a total of 141 documents produced by 357 authors from 101 different sources. A 15.6% international co-authorship was observed, and 16 authors were found to sign documents alone. On average, each document had 2.87 co-authors. The number of author words reached 455, while 5484 references were recorded, with an average of 16.82 citations per document. The annual growth rate of the field was 3.72%.

Figure 1 shows the trend of publications on this topic from 2004 to the present, March 2023. The data trend shows a growing trend in the number of publications over time, with some ups and downs. A significant increase in the number of publications is observed from 2007 onwards, peaking in 2016 and stabilizing around 15 annual publications from 2020 to the present (2023).

Figure 1

Publication Trend



4.1.1. Analysis of Sources (Journals)

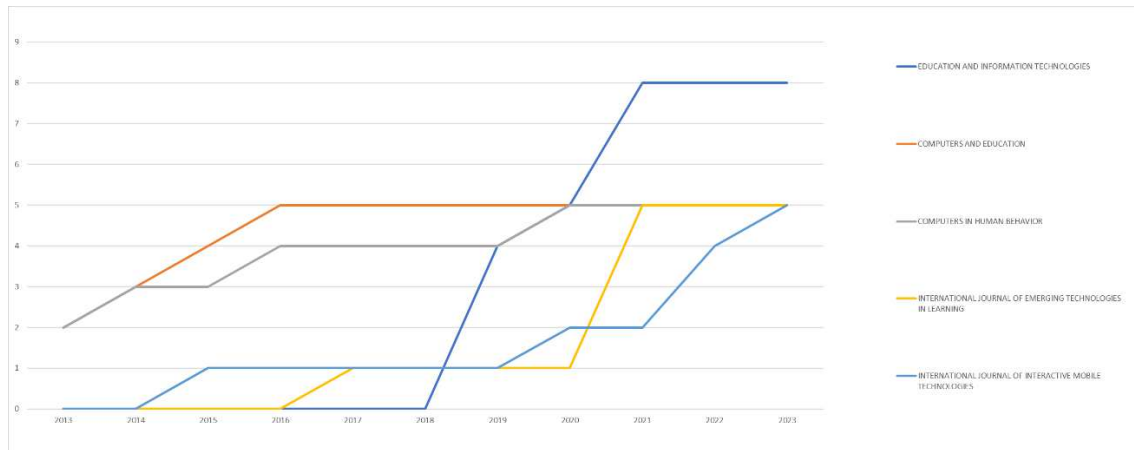
As previously mentioned, 141 articles have been published in 101 journals. We know that the top 10 journals with the highest number of publications represent 27.66% of all sources. The leading journal is "Education and Information Technologies" (5.67%), which addresses various topics related to education, computing, and the use of information and communication technologies (ICT) in different educational sectors. The journal aims to improve education and learning through the use of computing in various environments, platforms, and contexts and is considered Q1 by SJR. It is followed by "Computers and Education" (3.55%), which aims to increase knowledge and understanding of how digital technology can enhance education through the publication of high-quality research that expands theory and practice, and is considered Q1 by SJR.

According to the cumulative production dynamics of sources for the past ten years shown in Figure 2, the top five are "Education and Information Technologies," "Computers and Education," "Computers in Human

Behavior," "International Journal of Emerging Technologies in Learning," and "International Journal of Interactive Mobile Technologies."

Figure 2

Cumulative Production Dynamics of Sources



However, when talking about the top five local sources cited, we find "Computers & Education" (152), "Engineering Education" (63), "International Journal of Engineering Education" (56), and "Computers in Human Behavior" (55).

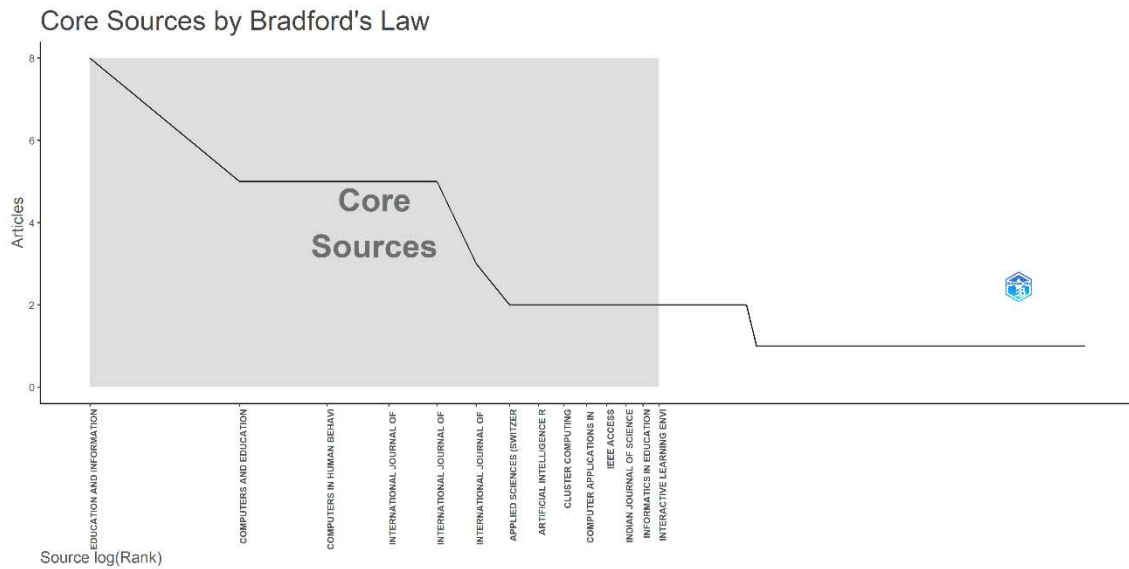
Regarding the five sources with the highest local impact (h-index), we have "Computers & Education" (5), "Computers in Human Behavior" (5), "Education and Information Technologies" (5), "Education and Information Technologies" (3), and "International Journal of Emerging Technologies in Learning" (3).

Bradford's Law is a valuable tool for finding the most relevant sources on a specific topic. This law establishes that publications in a given field are distributed in an exponential pattern, where only a few journals or sources account for most citations. The central zone or zone 1 includes the most cited journals, while zones 2 and 3 include less cited but still important journals. Researchers can use Bradford's Law to focus their bibliographic search and find the most important and relevant sources in their field.

According to this study and as observed in Figure 3, 14 journals are located in zone 1 or the central zone, which would correspond to the most frequently cited in the existing literature.

Figure 3

Source Grouping through Bradford's Law



4.1.2. Analysis of Authors

A total of 357 authors were identified for 141 articles. Analyzing fractional authorship, the ten authors with the highest fractional authorship are: Kolekar S.V. (1.67); Graf S. (1.53); Kinshuk K. (1.53); Pai R.M. (1); Chekour M. (1); Hafidi M. (1); Mahnane L. (1); Seghroucheni Y.Z. (1); Allioui Y.E. (1); and Alshmrany S. (1).

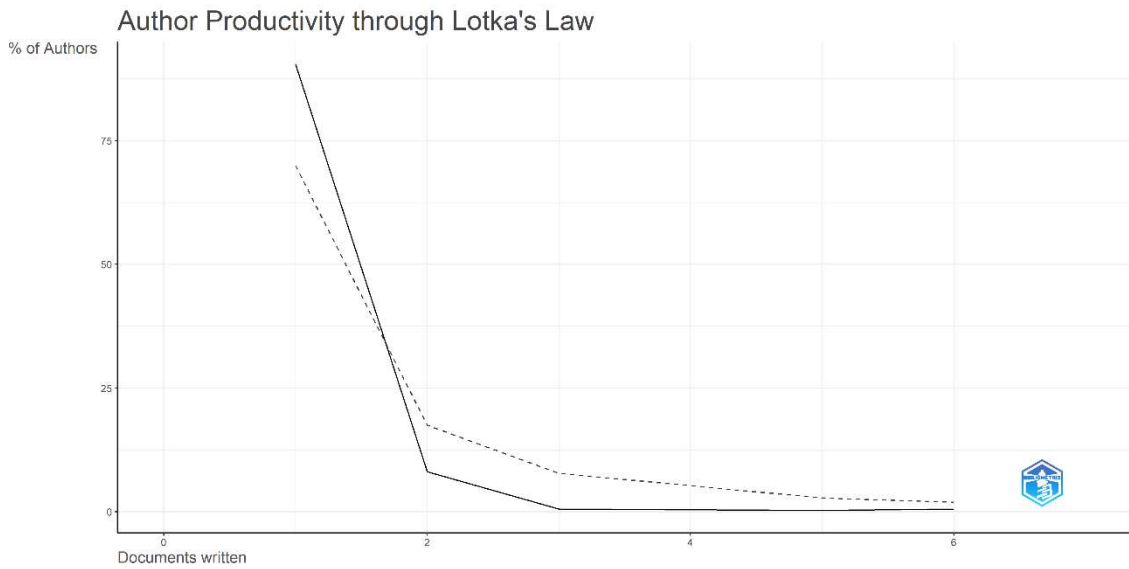
On the other hand, if we consider the number of published articles, the authors with the most publications are: Graf S. (6); Kinshuk K. (6); Campo M. (3); Pai R.M. (3); Agarwal A. (2); Azizan S.N. (2); Chekour M. (2); Chen N.S. (2); and Crockett K. (2).

Considering local citations (LC), the ten most relevant authors are: Darac D. (26); Bogdanovi Z. (26); Despotovic-Zrasic M. (26); Mihailovic D. (26); Vujin V. (26); Bilando S. (15); Khurshid K. (15); Mirza A.A. (15); Sohail K. (15).

Regarding Lotka's Law, which establishes the frequency of publications by author patterns in a specific field and period, it can be observed in this study that 90.5% of the authors produced a single document, 0.81% two documents, 0.06% three documents, 0.03% five documents, and 0.006% six documents, as shown in Figure 4.

Figure 4

Author Grouping through Lotka's Law

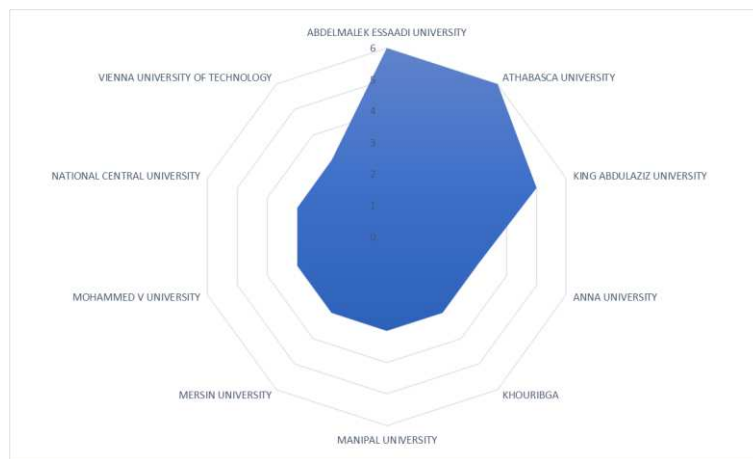


4.1.3. Analysis of Affiliations

The ten most relevant affiliations are: Abdelmalek Essaâdi University (Morocco), Athabasca University (Canada), King Abdulaziz University (Saudi Arabia), Anna University (India), Khouribga (Morocco), Manipal University (India), Mersin University (Turkey), Mohammed V University (Morocco), National Central University (Taiwan), Vienna University of Technology (Austria), as shown in Figure 5. These data demonstrate that the presence of European affiliations in research with our study topic is limited, as only 10% of the affiliations mentioned in the analysis belong to European universities.

Figure 5

Grouping of the Most Relevant Affiliations

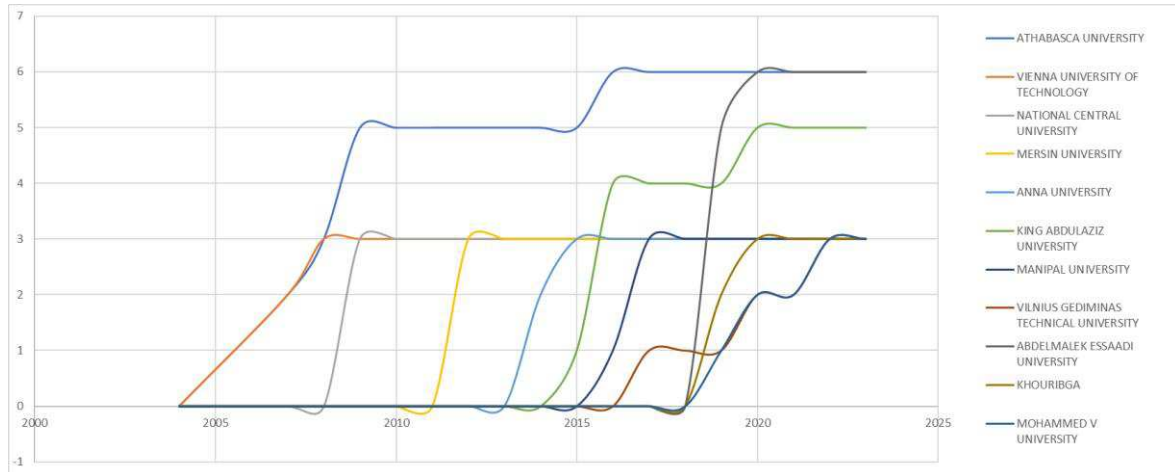


Regarding the publications by different affiliations over the years, Figure 6 shows that Athabasca University and Vienna University of Technology maintained a constant publication rate throughout the analyzed period, while National Central University did not publish any articles in 2004, 2007, and 2008 but experienced a gradual increase in the number of published articles from 2009 to the end of the analyzed period (2023), maintaining

three articles per year since then. Overall, all universities showed a steady growth in the production of articles over time.

Figure 6

Grouping of Publications by Affiliations over Time

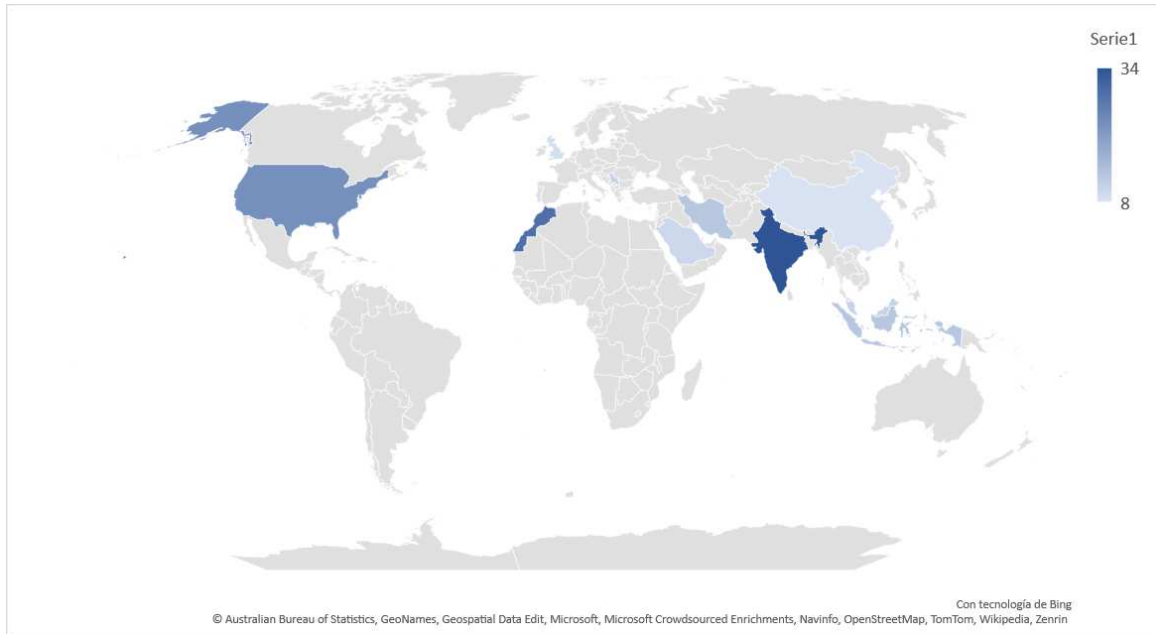


4.1.4. Analysis of Countries

Analyzing the ten countries with the highest number of publications, as shown in Figure 7, the United States leads the list with 34 publications, followed by the United Kingdom with 25, Spain with 16, India with 11, Bangladesh with 10, Australia with 9, Brazil with 8, Portugal with 7, and Germany and Italy both with 6 publications.

Figure 7

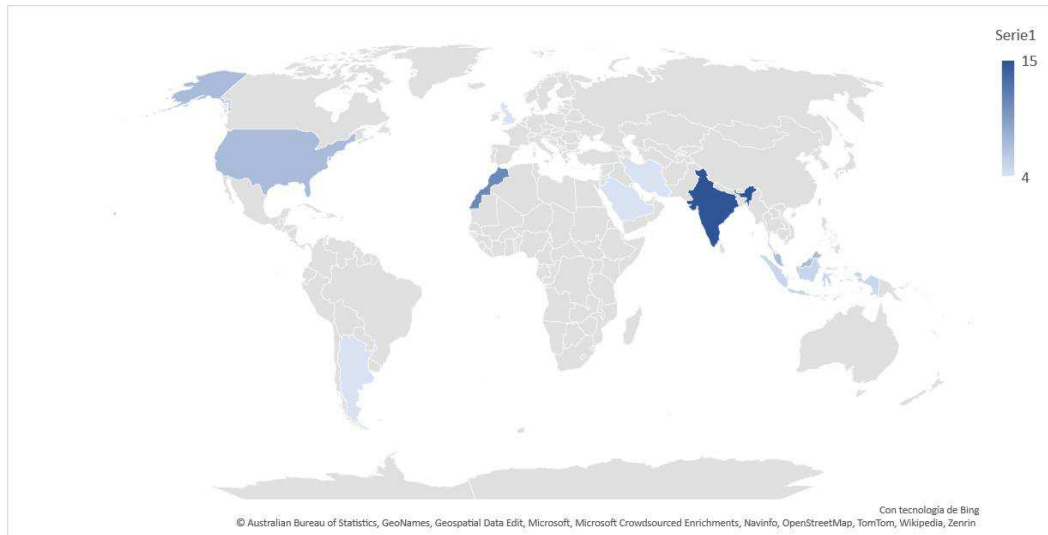
Countries with the Highest Number of Publications



Regarding the analysis of author publication by countries, the data barely change except for the inclusion of new countries at the expense of others. Among the top ten, as shown in Figure 8, we find the main authors correspond to: India (15); Morocco (11); Malaysia (7); United States (7); Indonesia (5); Argentina (4); Iran (4); Saudi Arabia (4); Turkey (4); and United Kingdom (4).

Figure 8

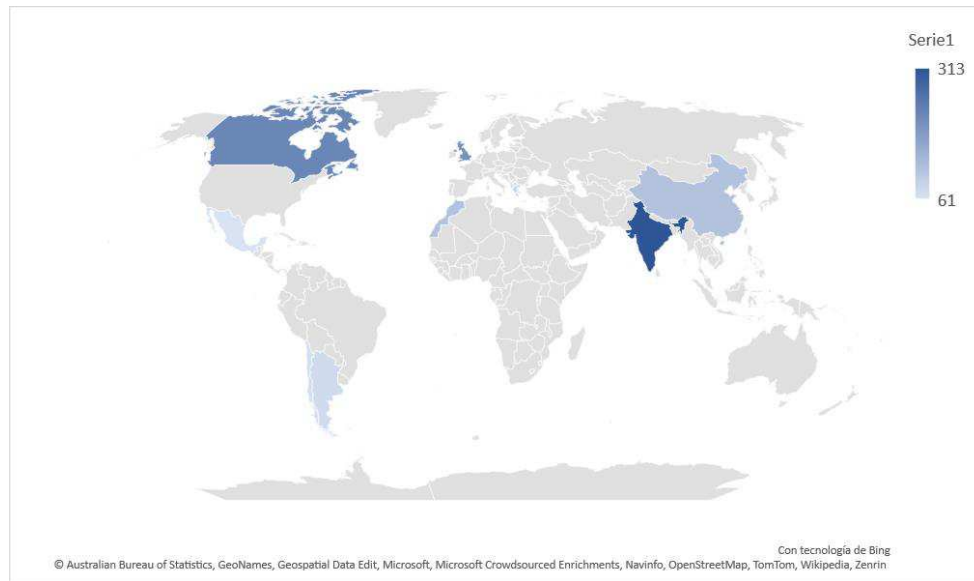
Authors in Countries with the Highest Number of Publications on the Study Topic



Regarding the number of citations (TC), as shown in Figure 9: India (313), Canada (224), United Kingdom (205), Turkey (173), Morocco (173), China (118), Greece (80), Argentina (76), Chile (66), Mexico (61).

Figure 9

Spatial Distribution of Total Citations (TC) for the Study Topic



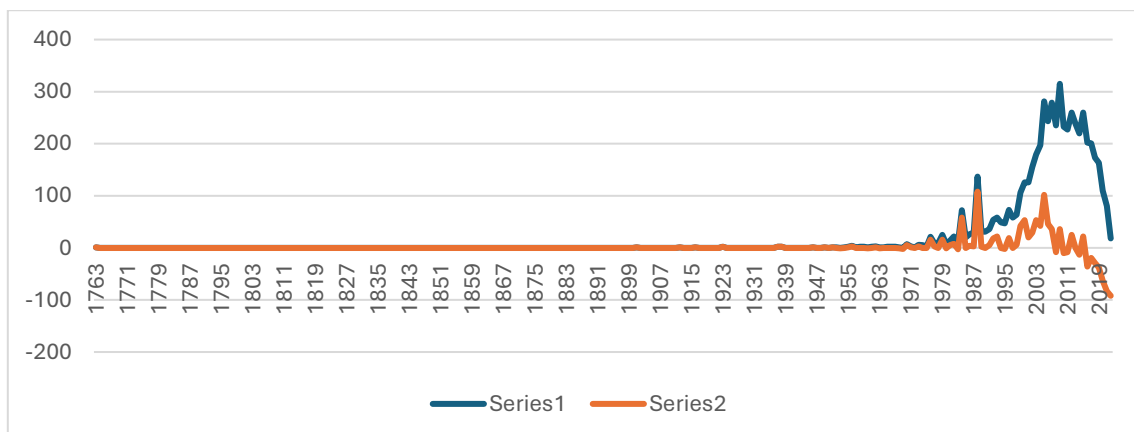
4.1.5. Analysis of Publication Documents

The most globally cited documents (GC) are: Graf S. 2007 J Res. Technolog. Educ. (GC-162); Graf S. 2009 Educational technology and society (GC-152); Özpölat E. 2009 Comput. Educ. (GC-143); Rani M. 2015 Knowl. Based. Syst. (GC-112); Graf S. 2009 Comput. Hum. Behave. (GC-89). Considering temporality and observing citations per year (GCpa), the results are: Rani M. 2015 Knowl. Based. Syst. (GCpa-12.44); Azzi I. 2020 Educ. Inf. Technol. (GCpa-10.13); Özpölat E. 2009 Comput. Educ. (GCpa-9.53); Graf S. 2007 J Res. Technolog. Educ. (GCpa-9.53); Ramírez-Correa P.E. 2017 Telematics Inf. (GCpa-9.43).

Publication year spectroscopy (RPY) will be used to know the year of the oldest references on the topic. A significant increase in the number of citations is observed from 2005 to 2009, followed by a gradual decline until 2014. Then, there is a rise again in 2015 and a significant decrease in recent years (2020-2022) (Fig. 10).

Figure 10

Publication Year Spectroscopy of References for the Study Topic



Therefore, in the descriptive analysis of document bibliographic attributes, several conclusions can be drawn.

Regarding the analysis of sources, we can confirm that the main sources are related to education and technology. The journals "Education and Information Technologies" and "Computers and Education" stand out. Additionally, the cumulative production dynamics of the sources in the last ten years show that these journals have maintained a constant presence in the field of educational research. On the other hand, considering the most cited and high-impact local sources, we find that "Computers & Education" and "Computers in Human Behavior" are the most prominent journals.

Regarding the analysis of authors, we have identified the most relevant authors and sources in the field of education and information technology. The authors with the highest fractional authorship and number of publications are Graf S. and Kinshuk K. Lotka's Law shows a highly skewed distribution in document production by authors, suggesting a concentration in scientific production.

Regarding the analysis of affiliations, the study on our research topic has revealed that a total of 357 authors produced 141 articles, and the ten authors with the highest fractional authorship, the authors with the most publications, and the ten most relevant authors according to local citations were identified. Additionally, the most relevant affiliations and their evolution in article production over time were analyzed. It was found that the presence of European affiliations is limited, and that Athabasca University and Vienna University have maintained a constant publication rate. In general, a steady growth in article production was observed for all analyzed universities.

The data analysis of countries shows that scientific production in our research field is led by authors from different countries, mainly the United States, United Kingdom, Spain, India, Bangladesh, Australia, Brazil, Portugal, Germany, and Italy. It also shows limited European affiliations, representing only 10% of the mentioned affiliations in the analysis. In terms of the universities with the highest scientific production, Athabasca University, Vienna University of Technology, and National Central University stand out for their constant publication rate. Finally, countries like India, Morocco, Malaysia, the United States, Indonesia, Argentina, Iran, Saudi Arabia, Turkey, and the United Kingdom are highlighted for their scientific production and citations received in the field of study.

From the analysis of publication documents, it can be seen that a small group of documents lead the list of the most globally cited in the field of educational technology, with authors like Graf and Özpölat standing out in several publications. Additionally, analyzing the temporality of citations shows a pattern of increase and decrease in the number of citations over time, peaking in 2009 and trending downward in recent years. The publication year spectroscopy (RPY) allows knowing the age of the oldest references on the topic and can be a useful tool for analyzing the evolution of a discipline over time.

4.2. Scientific Mapping

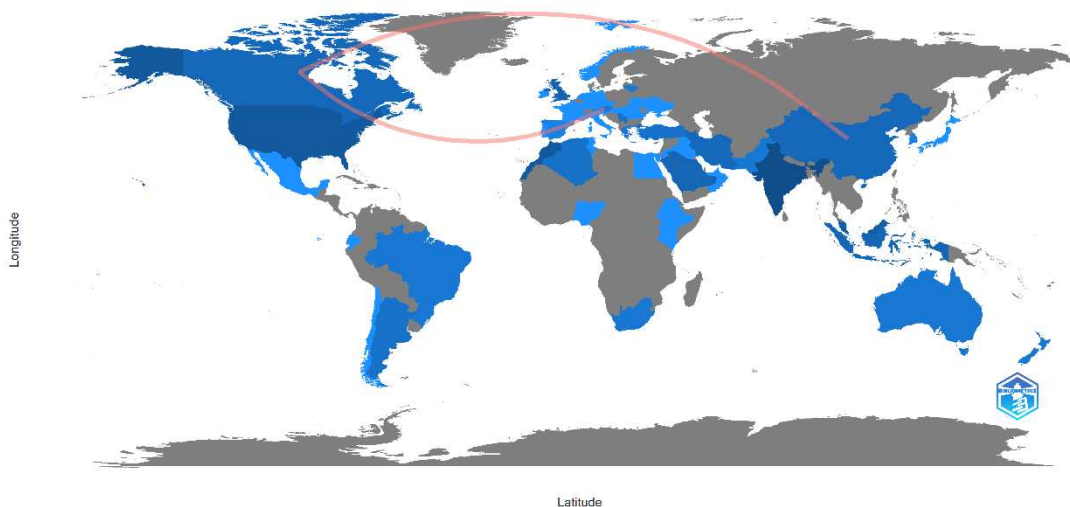
4.2.1. Academic Cooperation

First, we can observe the network of collaboration between countries in Figure 11, where the highest frequency network is between Canada and Austria, as well as between China and Canada.

Figure 11

World Collaboration Map between Countries

Country Collaboration Map



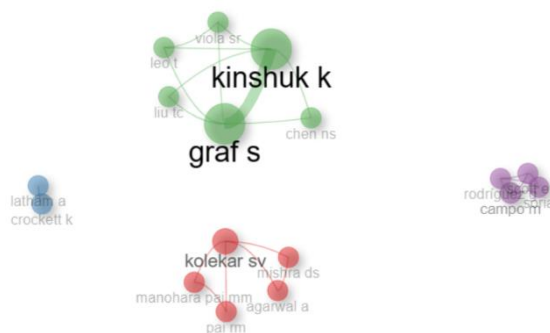
Network of Author Collaboration

The network of author collaboration provides information regarding Betweenness (measures the importance of a node in terms of how often it is on the shortest path between other nodes), Closeness (measures the accessibility of a node to other nodes in the network, i.e., how long it would take for a message or information to travel from that node to any other node), and PageRank (a measure of the relative importance of a node based on the number and quality of incoming links it receives).

In this regard, and observing Figure 12 of the 4 clusters, the standout nodes from cluster 3 (green) are Graf S. (B- 2.5; C-0.2; PR-0.098) and Kinshuk K. (B- 2.5; C-0.2; PR-0.098), and from cluster 1 (red) formed by Kolekar S.V. (B- 4; C-0.25; PR-0.093).

Figure 12

Author Collaboration Network

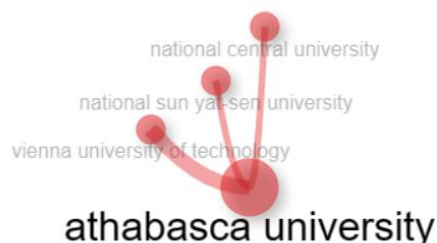


Network of Institutional Collaboration

The network of institutional collaboration, applying the same criterion as in the previous point, is shown in Figure 13, highlighting one cluster (red) formed by Athabasca University (B- 3; C-0.33; PR-0.47).

Figure 13

Institutional Collaboration Network



Network of Country Collaboration

The network of country collaboration, following the same criterion, is shown in Figure 14. Cluster 1 (red) is structured around Canada (B- 1; C-0.5; PR-0.48); China (B- 0; C-0.33; PR-0.25); Austria (B- 0; C-0.33; PR-0.25).

Figure 14

Country Collaboration Network



These three networks (authors, institutions, and countries) show different levels and types of collaboration between authors, countries, and institutions regarding recent topics in ILS research.

4.2.2. Co-citation Analysis of Sources, Documents, and Authors

In the co-citation network by articles (Fig. 15), the size of the nodes (the circles representing the articles) seems to vary, indicating the frequency of co-citation: larger nodes represent more frequently co-cited articles. The colors of the nodes correspond to different clusters, indicating themes or subfields of study within the general research area.

The edges between the nodes representing the co-citations show how the articles are related. Some nodes have denser connections, indicating that these articles are more frequently co-cited, strengthening the idea that they are related in terms of content or influence in the literature.

In our case, the co-citation analysis (Acedo et al., 2006) helps explore the intellectual connections between influential articles in a discipline and map the intellectual structure of the discipline (Calabretta et al., 2011; Culnan, 1987; White & Griffith, 1981; White & McCain, 1998).

In this network, nodes represent scientific documents, and edges represent the frequency with which two documents are cited together in other works.

Ultimately, it focuses on the technique of evaluating the influence and relevance of a specific article or author based on the number of times the article or author has been cited in other academic works. This technique is used to analyze the cognitive structure of a specific scientific field. The identification of study groups arises when a significant number of authors jointly cite a coherent group of articles. Regarding the evaluation of the influence and relevance of a scientific journal or information source, a similar technique is used based on the number of times articles published in that journal or source have been cited in other academic works.

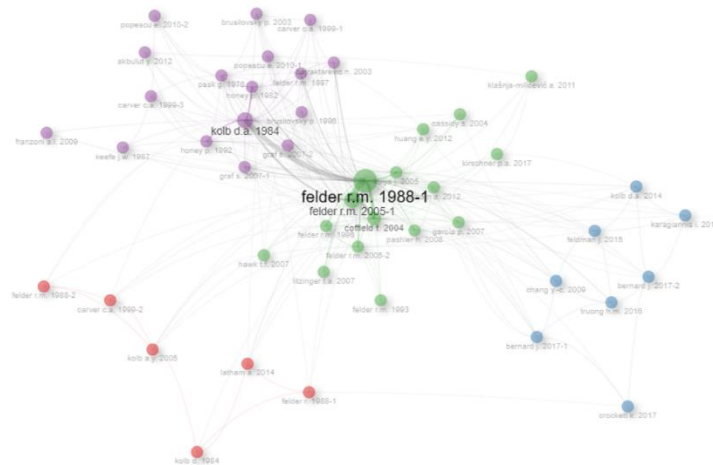
In our case, the co-citation network by articles (Fig. 15) identifies four clusters: cluster 1 (red) composed of 6 articles; cluster 2 (blue) composed of 8 articles; cluster 3 (green) composed of 16 articles and the most relevant; cluster 4 (purple) composed of 17 articles.

In the center of the network, an article ("felder_rm_1988-1")(Felder & Silverman, 1988) stands out, having significant connections with other nodes, indicating that it is a central and highly influential publication within the field of study, a seminal work frequently co-cited with many other works, indicating its importance in the development of research in this area.

The clusters appear to be organized around certain key articles, such as "kolb_da_1984" (Kolb, 1984) in the purple cluster and "felder_rm_2005-1" (Felder & Spurlin, 2005) near the green cluster, both of which have several connections and are significant articles in their respective topics.

Figure 15

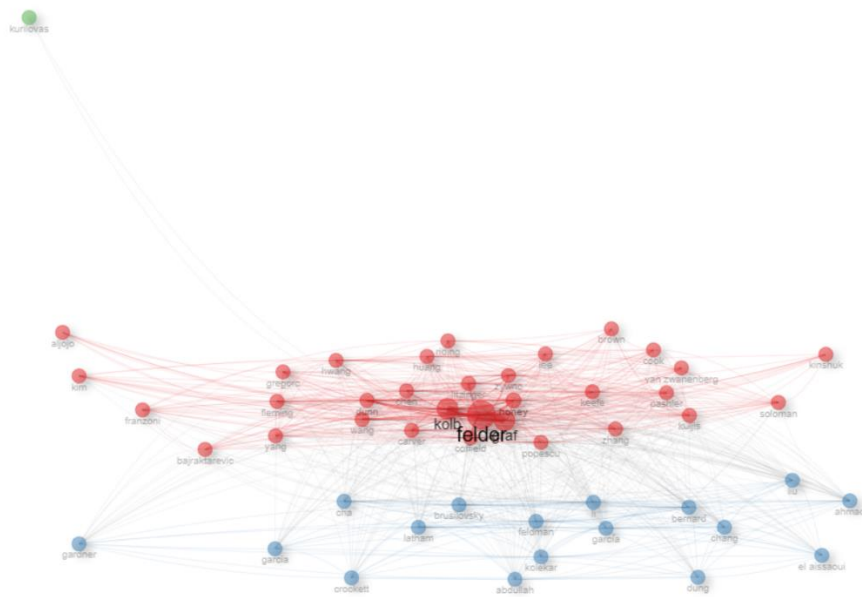
Co-citation Network by Articles



In the co-citation network by authors (Fig. 16), three clusters are identified: cluster 1 (red) composed of 32 authors and the most relevant; cluster 2 (blue) composed of 17 authors; cluster 3 (green) composed of 1 author.

Figure 16

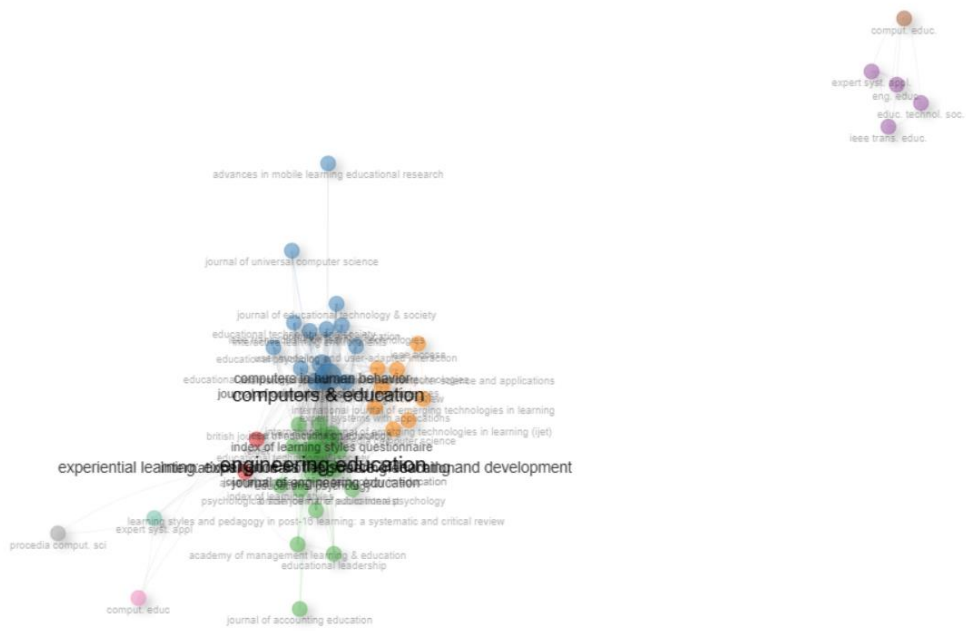
Co-citation Network by Authors



In the co-citation network by journals (Fig. 17), two important clusters are identified: cluster 1 (green) led by the "Engineering Education" journal and the most relevant, followed by cluster 2 (blue) where "Computers & Education" stands out.

Figure 17

Co-citation Network by Journals



4.3. Keyword and Critical Point Analysis

4.3.1. Most Used Keywords

Examining Keywords Plus, the ten most used learning keywords are: "learning style" (31), "learning systems" (24), "students" (22), "e-learning" (21), "teaching" (15), "computer-aided instruction" (13), "education computing" (12), "education" (11), "learning" (10), and "human" (8) (Fig. 18).

Figure 18

Most Used Keywords in Keywords Plus



Analyzing the titles, the top ten words are: "learning" (151), "styles" (67), "style" (33), "based" (27), "adaptive" (26), "e-learning" (26), "students" (26), "system" (19), "model" (18), "systems" (14) (Fig. 19).

Figure 19

Most Used Keywords in Titles



From the Abstracts, the top 10 words are: "learning" (1124), "styles" (398), "students" (365), "style" (303), "model" (187), "learners" (162), "study" (147), "based" (134), "results" (113), "system" (111) (Fig. 20).

Figure 20

Most Used Keywords in Abstracts



Regarding the most used keywords by authors, the top ten words are: "learning styles" (44), "learning style" (36), "e-learning" (18), "Felder-Silverman learning style model" (16), "FSLSM" (10), "adaptive e-learning systems" (6), "intelligent tutoring systems" (6), "Moodle" (6), "ontology" (6), "interactive learning environments" (5) (Fig. 21).

Figure 21

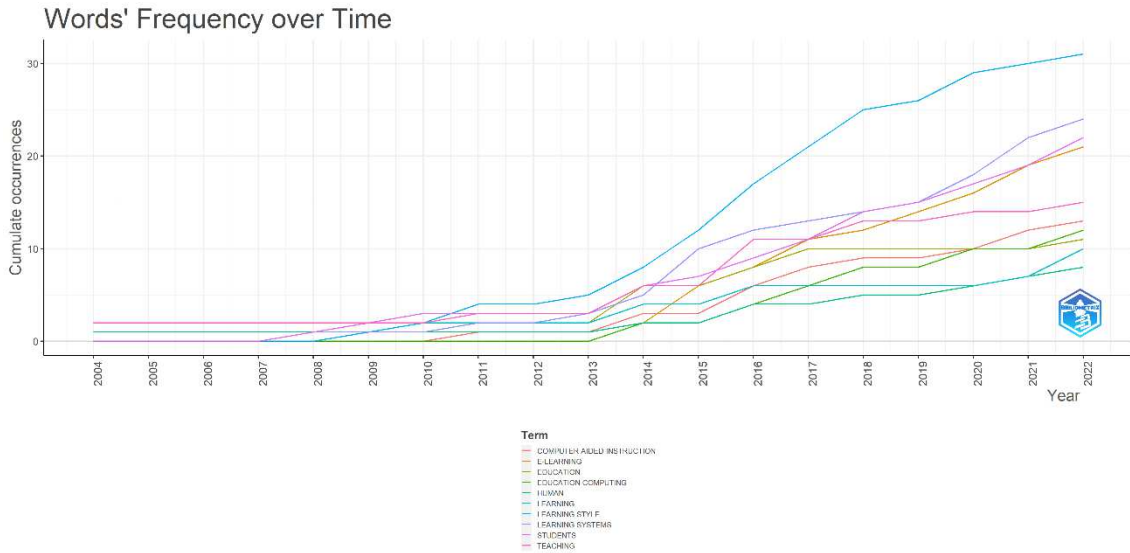
Most Used Keywords by Authors



To delve into temporal trends, we used the cumulative thematic analysis of words. For example, "learning style" is the most used word in Keywords Plus, showing a growing trend from 2009 to 2015. From 2016 onwards, its growth is even more significant and continues to the present. The word "learning systems" has a practically similar trend to the previous word, although below it. The word "students" shows a similar trend but with a higher growth from 2013, surpassing "learning systems" in 2019 and equalizing with "e-learning" in 2021, indicating the importance of applying learning styles in online teaching, although "students" again outpaces in 2022. Therefore, the keywords increasing in order are: "learning style," "learning systems," "student," and "e-learning" (Figure 22). Regarding Author's Keywords, "learning style" and "learning systems" stand out significantly over others; in Titles, the most cited word is "learning," the same as in the Abstracts.

Figure 22

Cumulative Thematic Analysis of Keywords Plus



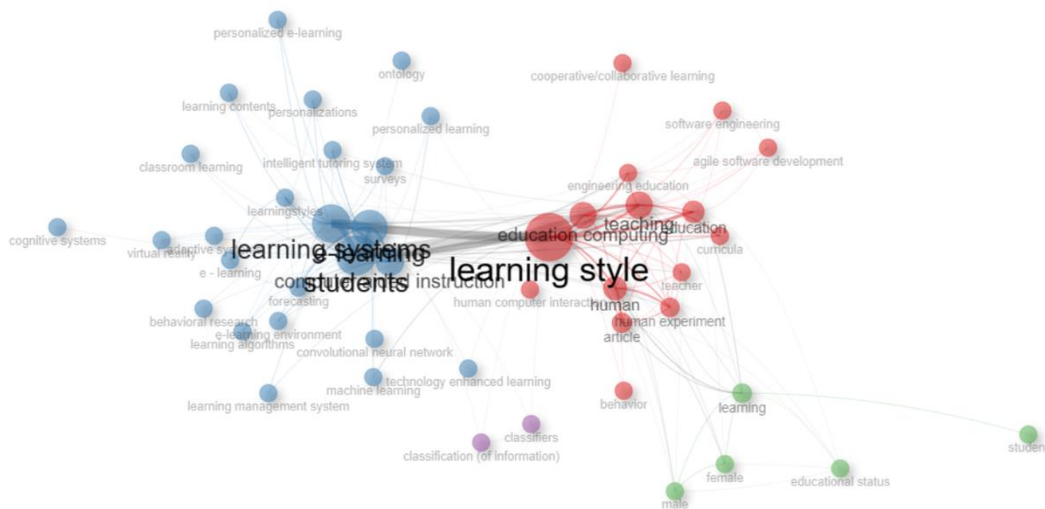
4.3.2. Co-occurrence Network

The co-occurrence network is a bibliometric analysis tool used to analyze key terms found in a set of documents. It is a common way to visualize possible connections between people, organizations, concepts, and other entities in a text.

From the analysis of the co-occurrence network of Keywords Plus, we can see four clusters. The co-words with the highest scores from the main groups based on betweenness are: "learning style" (393.09) for cluster 1, "learning systems" (170.86) for cluster 2, "e-learning" (141.67) for cluster 2, "computer-aided instruction" (74.96) for cluster 2 (Figure 23).

Figure 23

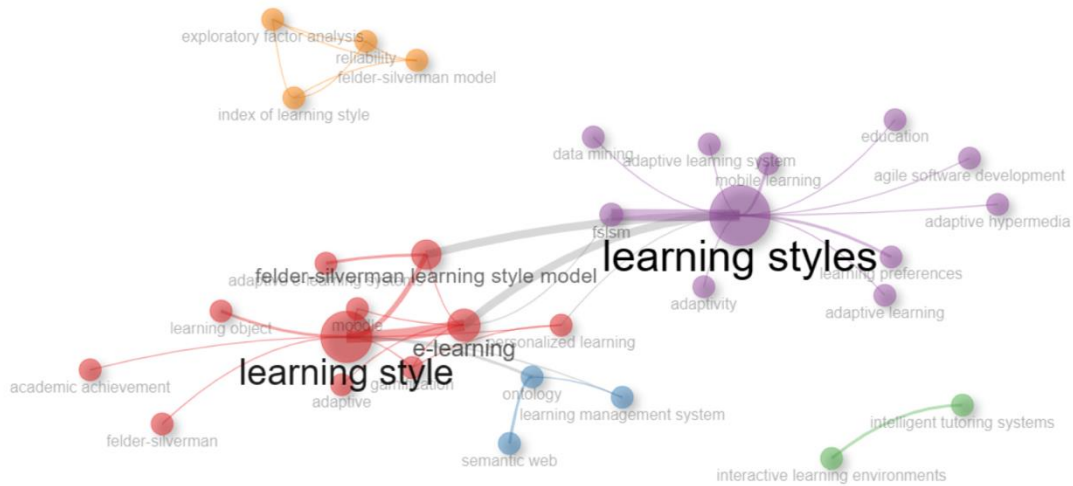
Co-occurrence Network Analysis of Keywords Plus



From the analysis of the co-occurrence network of Author's Keywords, we can see five clusters. The co-words with the highest scores from the main groups based on betweenness are: "learning styles" (175.64) for cluster 4, "learning style" (125.97) for cluster 1, "e-learning" (90.10) for cluster 1, "Felder-Silverman learning style model" (48.92) for cluster 1, and "ontology" (23) for cluster 2 (Figure 24).

Figure 24

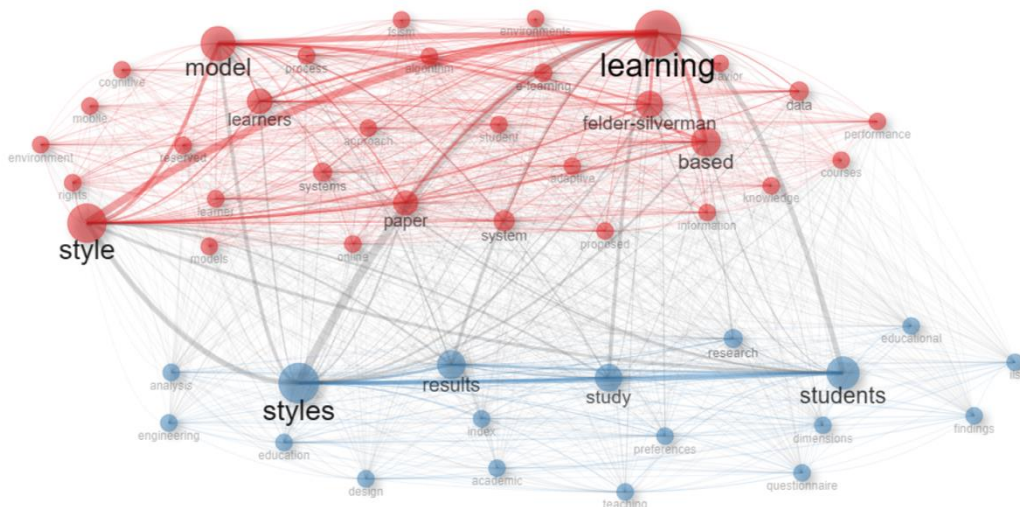
Co-occurrence Network Analysis of Author's Keywords



Through the analysis of the co-occurrence network of Abstracts, we can see two clusters. The co-words with the highest scores from the main groups based on betweenness are: "learning" (6.33) for cluster 1, "styles" (4.56) for cluster 2, "style" (4.51) for cluster 1, "model" (3.16) for cluster 1, and "students" (2.44) for cluster 2 (Figure 25).

Figure 25

Co-occurrence Network Analysis of Abstracts



The most notable observation is that in Keywords Plus, "learning style" is in a different cluster from "learning systems." The former is accompanied by aspects more related to education from the teacher's perspective ("teaching," "education," "education computing," "teacher," "student," etc.), while the latter is more related to the student and practicality aspects ("students," "computer-aided instruction," "e-learning," etc.).

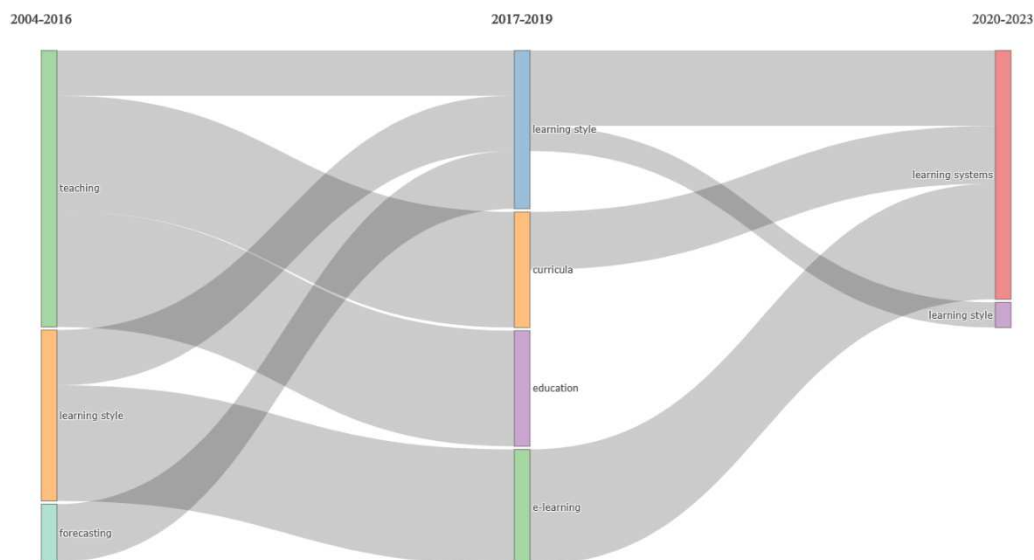
4.3.3. Research Trajectory

It is essential to perform a thematic development analysis to observe how the collection of topics has evolved over time and through subphases. To achieve this, we divided the total study period (2004-2023) into three time segments: 2004-2016, 2017-2019, and 2020-2023 to identify temporal trends.

It seems evident that significant changes in trends have occurred between the periods studied. The first period (2004-2016) and in Keywords Plus was characterized by conceptual understanding where three major trends predominated in order of importance: "teaching," "learning style," and "forecasting." However, in the second period (2017-2019), implementation began, diversifying these trends. Thus, "teaching" diversified into "learning style," "curricula," and "education." "Learning style" logically maintained its relationship with itself but opened significantly to "e-learning." Finally, "forecasting" diversified between "learning style" and "e-learning." In the third period (2020-2023), final implementation, the themes were simplified into one major theme, "learning systems," followed to a lesser extent by "learning style." In short, there was a separation between the more learning aspects at the beginning and those directly related to learning styles (Figure 26).

Figure 26

Thematic Development Analysis in Keywords Plus



In the first period (2004-2016) and in Author's Keywords, there were already several themes related to learning styles ("index of learning styles," "learning style," and "learning styles") but were linked to intelligent tutoring systems ("intelligent tutoring systems"). In the second period (2017-2019), learning styles were introduced, introducing "e-learning," which was linked to "learning styles." In the third period (2020-2023), final

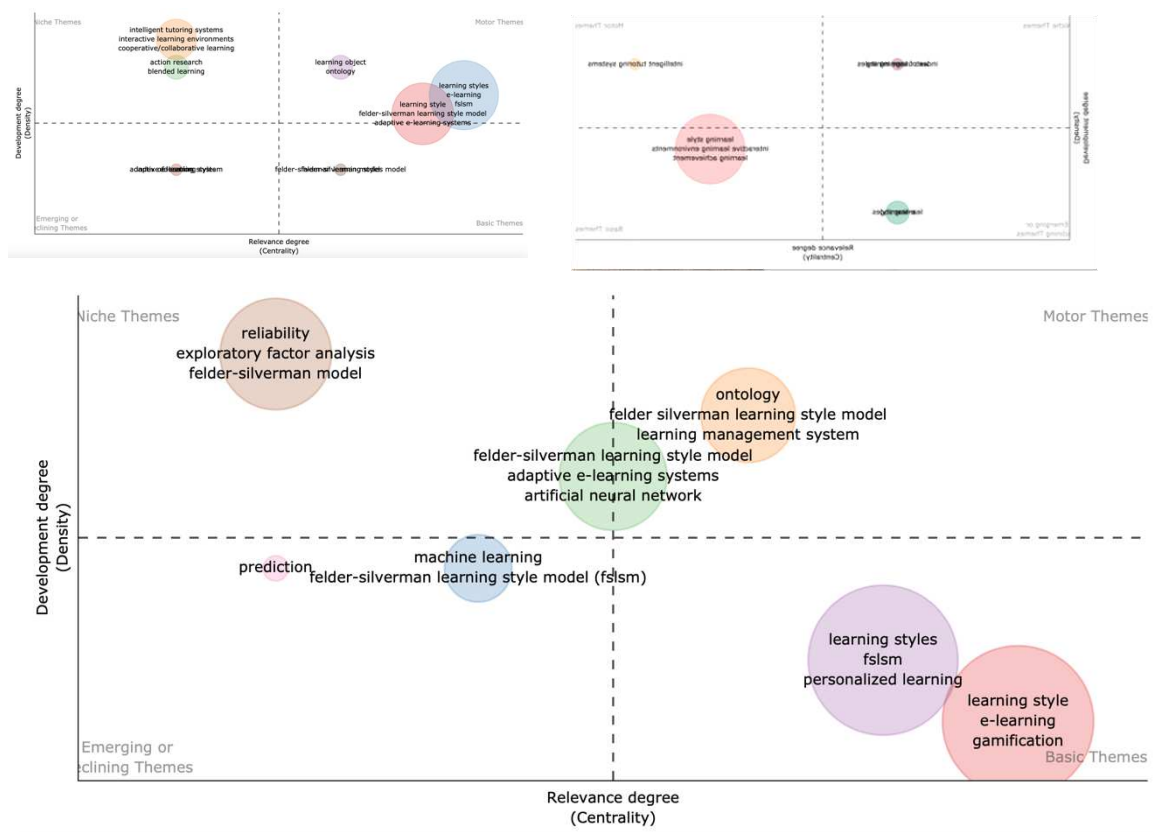
implementation, the themes were simplified into one major theme, "learning style," which here wins over "learning systems." In short, there was a separation between more theoretical aspects

at the beginning, passing through the introduction of e-learning, and those directly related to learning styles.

This trend of separation can also be noted in the strategic diagrams, although it is possible to delve deeper into it. During the first period and in Author's Keywords, we see that as important themes in scientific development (motor themes), "learning style" and "learning styles" appear, linked to the Felder-Silverman model, with an isolated theme like ontology appearing (Figure 27a). However, in the second period, a change occurs, giving priority to intelligent tutoring systems. However, themes related to "learning style" have less scientific development by themselves (Figure 27b). In the third period, themes related to learning styles, particularly linked to e-learning or learning management systems, consolidate as motor themes (Figure 27c).

Figure 27

Strategic Diagrams in Author's Keywords

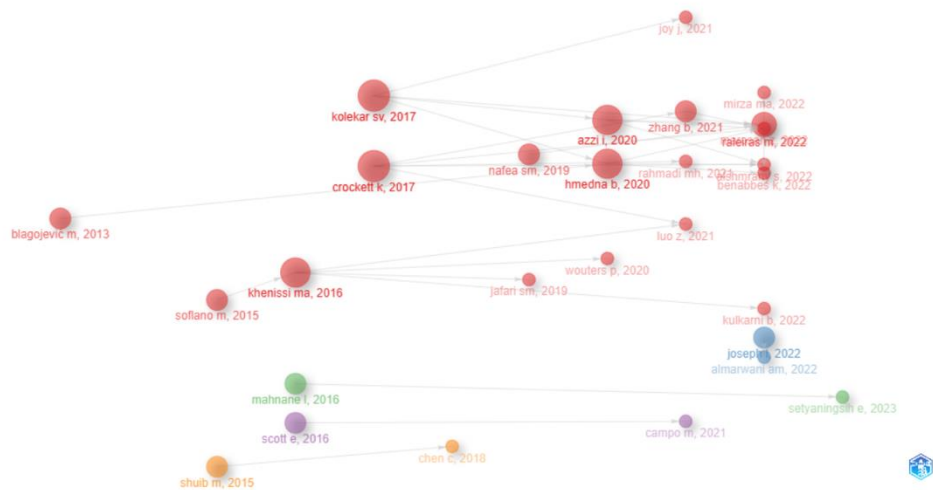


Through historiography, we can understand which works have been most frequently cited by other works over time (annually) using local citation score (LCS) and global citation score (GCS). A dual origin of research could be established: on one hand, in 2013, we would have Blagojevic M. with a research trajectory until the present, primarily in more generic learning styles and only partially in the Felder-Silverman style. On the other hand, in 2015 and 2016, we have Soflano M. and Khenissi M.A., respectively. In this case, the research focuses more on the Felder-Silverman style.

Although the condensation of citations generally, but especially in the first type of research, begins to increase from 2017, it reached a high position from 2020 to the present. The most relevant cluster (red) is concentrated around the works with the highest GCS, which are Crockett K. 2019, Kolekar S.V. 2017, and Azzi I. 2020, all from the first research line (Figure 28).

Figure 28

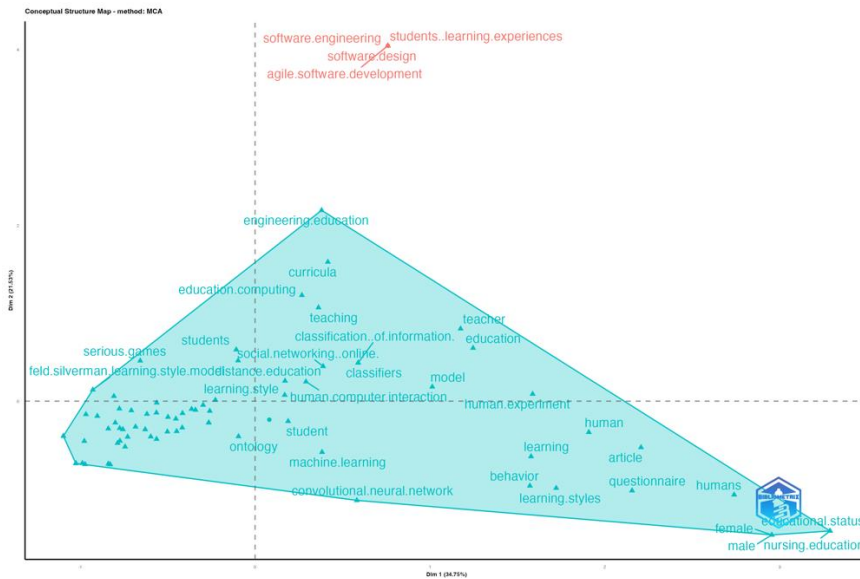
Historiography



Finally, multiple correspondence analysis (MCA) was performed to detect and elucidate underlying structures in nominal category data. From the conceptual structure map of Keywords Plus generated with MCA, two clusters of two dimensions (34.75% and 21.53%) emerge (Figure 29). Additionally, two clusters in two dimensions appear for both author's keywords and titles and abstracts.

Figure 29

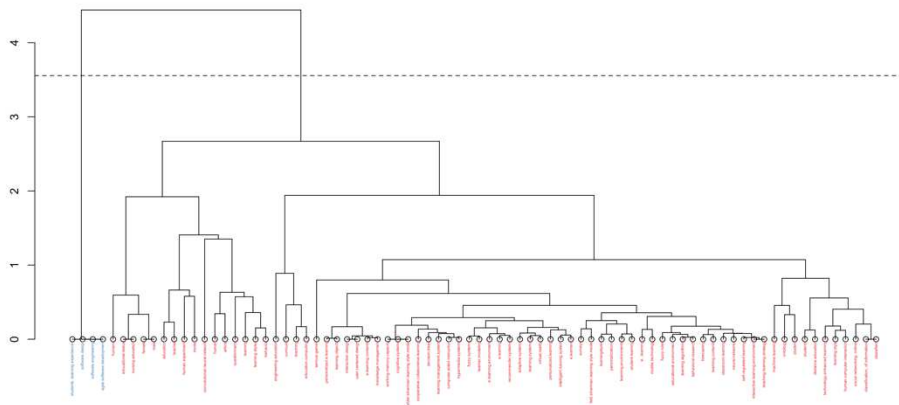
Multiple Correspondence Analysis (MCA)



All this information can be visualized using thematic dendrograms; in our case, we reproduce the thematic dendrogram of Keywords Plus (Figure 30).

Figure 30

Thematic Dendrogram of Keywords Plus

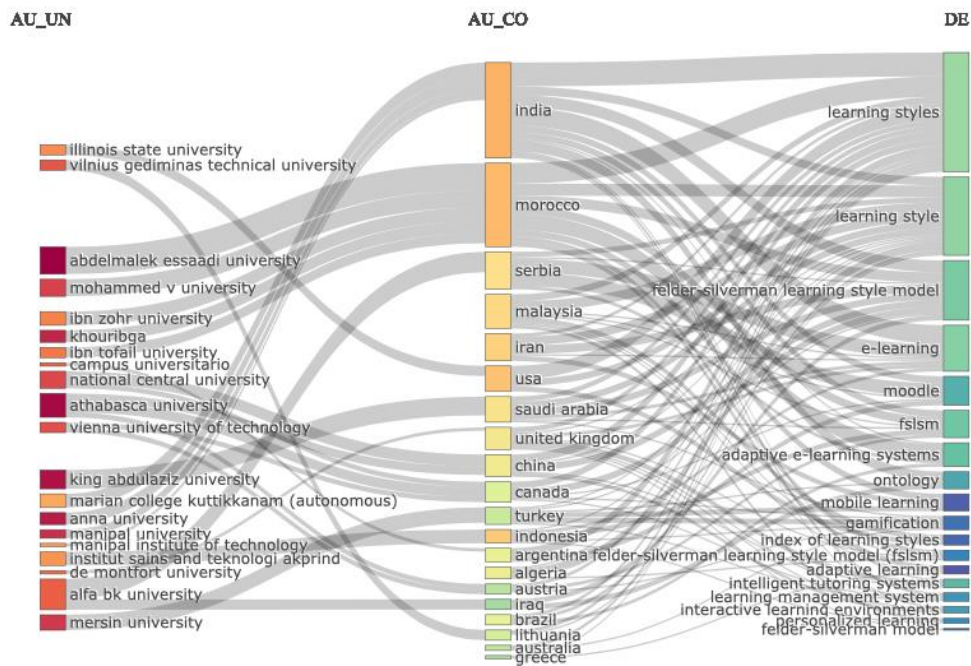


Similarly, we created a three-field graph for affiliations, countries, and research focus with the best performance in our analysis. Affiliations are shown on the left, countries in the middle, and research focus keywords on the right. From this graph, it can be concluded that the leading countries in research are not European (India, Morocco). They are followed by other countries with a single European representative (Serbia), along with Malaysia and Iran, followed by the USA. Next are Saudi Arabia and England, followed by China, Canada, and Turkey.

As we have seen before, some of the most important keywords are related to learning styles, the Felder-Silverman model, and e-learning, which is quite consistent with them being predominant in the current research focus (Figure 31).

Figure 31

Three-field Graph for Affiliations, Countries, and Research Focus with Best Performance in Our Research



From the Keyword and Critical Point Analysis section, several interesting conclusions can be drawn.

Based on the provided keywords and titles, we can infer that the main research topic is learning and different learning styles. There is also an emphasis on the use of learning systems and educational technologies, especially online education (e-learning) and computer-assisted instruction. Students and their academic performance are also a recurring topic in the analyzed studies. Finally, the word "human" appears in the keyword list, suggesting that there may also be studies focusing on the relationship between learning and the human factor in the educational process.

Interestingly, it seems that authors focus on learning styles and online education, referencing specific models like the "Felder-Silverman learning style model," the subject of our study. Adaptive e-learning systems and intelligent tutoring systems are also mentioned. Additionally, there are references to specific technologies used in online education, such as "Moodle" and "ontology."

It is notable how the use of these keywords has evolved over time and how they have become increasingly important topics in educational research. It seems that the focus on learning styles and learning systems has increased in recent years, and online teaching and adaptation to students' needs are becoming increasingly important topics.

Identifying the clusters and the most relevant co-words in each of them can help better understand the topics addressed in studies on learning styles and online learning systems. For example, in Keywords Plus, cluster 1's most relevant co-word is "learning style," suggesting that this topic is of great importance in studies in this area. In cluster 2, the most relevant co-words are "learning systems" and "e-learning," indicating that these topics are also fundamental. In Author's Keywords, cluster 4 is dominated by the co-word "learning styles," indicating that this topic is central in the authors' studies. In cluster 1, the most relevant co-words are "learning style," "e-

learning," and "Felder-Silverman learning style model," suggesting that these topics are interrelated. Finally, in the Abstracts, cluster 1 is dominated by the co-word "learning," while cluster 2 is centered on "styles."

It is worth noting how Keywords Plus clusters reflect a distinction between the more theoretical and practical aspects of education and learning. On the one hand, the "learning style" cluster focuses on the theory of learning styles and their application in the educational process, while the "learning systems" cluster concentrates on the implementation of learning systems and educational technologies in practice.

Additionally, the clusters of Author's Keywords and Abstracts show a greater diversity of terms, reflecting the variety of approaches and topics addressed in the articles. However, some main topics can still be identified, such as learning styles, educational technology, and online teaching.

Regarding research trajectories, this study analyzes the evolution of research on learning styles over three periods (2004-2016, 2017-2019, and 2020-2023) and identifies significant changes in trends and topics through sub-phases. There is a trend towards the separation and consolidation of topics, with those related to learning styles increasingly linked to current educational technology, particularly e-learning and learning management systems. The analysis of local and global citation scores allowed identifying the most cited works and establishing the research trajectory in the field of learning styles. Multiple correspondence analysis (MCA) was used to identify patterns and relationships between categorical variables, and it is concluded that the leading research countries are not European, with India and Morocco at the top of the list.

6. DISCUSSION

This research has explored different learning style models and their impact on the teaching process through a rigorous and systematic bibliometric analysis. The obtained results have demonstrated that learning styles are a set of individual needs, objectives, and preferences that affect students' learning processes (Ally, 2010; Kadam et al., 2021; Mohamad, 2013; Noor et al., 2023).

Regarding the research trajectory, a trend towards the separation and consolidation of topics has been identified, with those related to learning styles increasingly linked to current educational technology, particularly e-learning and learning management systems. Additionally, significant changes in trends and topics through sub-phases have been identified. The most prevalent learning style methods in different search engines are VAK/VARK, CHAEA, and ILS (Diago et al., 2021, pp. 96, 103, 104, and 111). These models have been the subject of numerous studies in recent decades, demonstrating their relevance and importance in the educational field.

Studies on learning styles have been widely debated. Coffield et al. (2004), Kirschner (2017), and Husmann and O'Loughlin (2018) have mainly focused their criticisms on the VARK taxonomy, ignoring other classifications in this field. These criticisms do not acknowledge studies conducted in languages such as Spanish and Portuguese (Pérez, 2022).

In a different approach, the work of Hu J., Peng Y., Chen X., and Yu H. (2021) addresses the differentiation of learning styles in university students from various disciplines. Using a machine learning algorithm, specifically support vector machine (SVM), and an additional technique known as recursive feature elimination (SVM-RFE), the authors analyzed the learning styles of 790 students from 46 specializations in a blended learning course. On the other hand, Quintanal (2022) investigated the relationship between learning styles and academic performance in the subject of Physics and Chemistry for first-year high school students in the Science modality. The main purpose of this research was to identify learning style preferences and promote meaningful learning through an innovative methodology based on gamification, using a specific survey. On the other hand, Martínez et al. (2021) focused on analyzing and discussing evidence supporting or refuting certain myths generated by

Information and Communication Technologies (ICT) in the educational field. This analysis included topics such as multitasking, digital natives, learning styles, video games, and connectivism, considered by some as a new educational theory.

The bibliometric analysis we conducted is a research technique increasingly used in educational studies. Studies on learning styles have been widely debated. Coffield et al. (2004), Kirschner (2017), and Husmann and O'Loughlin (2018) have mainly focused their criticisms on the VARK taxonomy, ignoring other classifications in this field. These criticisms do not acknowledge studies conducted in languages such as Spanish and Portuguese (Pérez, 2022).

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The bibliometric analysis on online education conducted by Abuhassna et al. (2022), for example, identified the main research areas in this field, such as motivation, technology, and learning quality. They analyzed 1371 publications documented in the Scopus database from 2010 to 2020. The results identified the most relevant topics covered by the journal. Additionally, several emerging topics were identified, such as digital learning, online learning environments, and self-directed learning. Another bibliometric analysis identified the main research areas related to LMS, such as its impact on academic performance and its effectiveness in improving learning quality (Pham-Do et al., 2022). The study is based on a systematic review of literature published in Scopus and uses bibliometric techniques to analyze trends, patterns, and characteristics of LMS research in developing countries. An interesting bibliometric review on Mobile Learning in Higher Education was conducted by Sobral (2020). The objective of this review was to analyze the scientific production on mobile learning in higher education in journals indexed in the Scopus and Web of Science databases. The sample consisted of 450 articles in total (Sobral, 2020). The bibliometric analysis conducted by Pratiwi et al. (2022) identified the main research areas related to discovery-based learning, such as its impact on academic performance and its effectiveness in improving learning quality. The VOSviewer tool was used to visualize networks of authors, countries, journals, and keywords. Similarly, the bibliometric analysis conducted by Ezugwu et al. (2023) identified the main research areas related to machine learning, such as its practical applications and economic impact. Sökmen et al. (2023) also conducted a bibliometric analysis, in their case, on self-regulated learning in primary education. The authors used the bibliometric analysis tool VOSviewer to visualize relationships between studies and keywords in this field. They examined 526 studies conducted between 1994 and 2020 using keywords. Noor et al. (2023) analyzed students' learning preferences in Construction Technology courses using the VARK model. They identified dominant learning styles and highlighted the importance of aligning teaching methods with individual learning styles. Karapetyan (2015) considered two learning style models and examined their impact on students' performance in an English as a Foreign Language (EFL) classroom.

Regarding the future evaluation of the proposed work, it can be affirmed that our bibliometric analysis provides valuable information for future research on learning styles. The obtained results allow for a better understanding of how these models, particularly the ILS, affect the current educational process and how they are evolving as new technologies are integrated. Additionally, this study demonstrates the importance of the systematic and rigorous use of bibliometric analysis to ensure the reliability and validity of the obtained results.

7. CONCLUSIONS

The bibliometric analysis conducted reveals several important conclusions. Regarding the sources, the constant presence of the journals "Education and Information Technologies" and "Computers and Education" in the field of educational research is highlighted, and the journals "Computers & Education" and "Computers in Human Behavior" are the most cited and with the highest impact.

Regarding the authors, Graf S. and Kinshuk K. are identified as the most relevant in the field of education and information technology. Additionally, a concentration in scientific production is observed, suggested by the highly skewed distribution in document production by authors.

Regarding affiliations, it is found that the presence of European affiliations is limited, and Athabasca University and Vienna maintain a constant publication rate.

Scientific production is led by authors from different countries, mainly the United States, United Kingdom, Spain, India, Bangladesh, Australia, Brazil, Portugal, Germany, and Italy.

In the scientific mapping analysis, active collaboration between authors, institutions, and countries in educational technology research is highlighted, suggesting a strong and committed scientific community in this field of study. Graf S., Kinshuk K., and Kolekar S.V., as well as Athabasca University, are identified as important nodes in the author and institutional collaboration networks, respectively. On the other hand, Canada, China, and Austria are identified as key countries in the country collaboration network. Therefore, this analysis has demonstrated that there is active collaboration between authors, institutions, and countries in ILS research, suggesting a strong and committed scientific community in this field of study.

On the other hand, the co-citation analysis has allowed for the exploration of intellectual connections between influential articles and authors in a discipline, mapping its intellectual structure. The obtained results have identified several clusters in both networks, particularly highlighting the most relevant cluster in the co-citation network, composed of 17 articles, and in the author collaboration network, composed of 32 authors. These findings significantly contribute to understanding the dynamics of research in the studied discipline.

Regarding research trajectories, this study has analyzed the evolution of research on learning styles over three periods (2004-2016, 2017-2019, and 2020-2023), identifying significant changes in trends and topics across sub-phases. There is a trend towards the separation and consolidation of topics, with those related to learning styles increasingly linked to current educational technology, particularly e-learning and learning management systems. Additionally, significant changes in trends and topics have been identified across sub-phases. The learning style methods that are most prevalent in various search engines are VAK/VARK, CHAEA, and ILS (Diago et al., 2021, pp. 96, 103, 104, and 111). These models have been the subject of numerous studies in recent decades, demonstrating their relevance and importance in the educational field.

The analysis of local and global citation scores allowed for the identification of the most cited works and the establishment of the research trajectory in the field of learning styles. Multiple Correspondence Analysis (MCA) was used to identify patterns and relationships between categorical variables, concluding that the leading countries in research are not European, but rather India and Morocco top the list.

Therefore, this research has explored different learning style models and their impact on the teaching process through a rigorous and systematic bibliometric analysis. The obtained results have demonstrated that learning styles are a set of individual needs, objectives, and preferences that affect students' learning processes (Ally, 2010; Kadam et al., 2021; Mohamad, 2013; Noor et al., 2023).

8. PROPOSAL FOR FUTURE EVALUATION

It can be affirmed that our bibliometric analysis provides valuable information for future research on learning styles. The obtained results allow for a better understanding of how these models, particularly the ILS, affect the current educational process and how they are evolving as new technologies are integrated. Additionally, this study demonstrates the importance of the systematic and rigorous use of bibliometric analysis to ensure the reliability and validity of the obtained results.

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