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Mapping the evolution of learning analytics in education: unveiling trends and insights

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Abstract
This study maps research trends in Learning Analytics (LA) through a large-scale bibliometric synthesis covering 2014–2023. Records retrieved from Web of Science and Scopus were de-duplicated and screened with an adapted, transparency-oriented PRISMA workflow, yielding a final corpus of 2245 peer-reviewed journal articles. Using VOSviewer and R, we computed standard indicators (citation, co-citation, co-authorship, bibliographic coupling, and keyword co-occurrence) and thematically examined the 20 most-cited LA papers against the LA reference model. Findings show a marked acceleration of LA publications after 2018; the USA, Australia, Spain, China, and England serve as central collaboration hubs, with Monash University, the Open University, and the University of Edinburgh among the most influential institutions. Keyword structures position "higher education," "machine learning," and "educational data mining" as core topics, while AI-enabled and multimodal analytics emerge as growth areas. The analysis also reveals persistent gaps: the "Who" (stakeholders) and, to a lesser extent, the "What" (data environments) dimensions remain underrepresented in seminal work. By integrating two major databases and combining macro-level mapping with a targeted appraisal of landmark studies, this paper offers an up-to-date overview of LA's evolution and highlights actionable priorities. We conclude that future research should prioritize interdisciplinary and international collaboration, ethical and stakeholder-centric design, and AI-supported, multimodal approaches to enhance impact and generalizability.

Keywords Artificial intelligence · Learning analytics · Bibliometric analysis · LA reference model · Co-authorship analysis

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1 Introduction

Technological innovations drive the integration of new methods in education, while growing student numbers and evolving learner expectations lead to more flexible and developed educational systems. These factors highlight the pursuit of ideal learning environments and improved education quality. In this context, Learning Analytics (LA) is increasingly recognized as a critical instrument for data-driven decision-making in education, offering educators insights into student engagement, progress, and challenges (Ferguson 2012; Viberg et al. 2018; Palanci et al. 2024). By providing insights into each student's needs, LA provides valuable data to support students in reaching their full potential. However, despite its growing adoption, the field of LA lacks a comprehensive, critical synthesis of its development, methodologies, and trends in educational research (Gašević et al. 2015; Khalil and Ebner 2016).

Over the last decade, LA has increasingly focused on improving student achievement, shaping educational policies, and enhancing educational processes. By integrating education, IT, and data science (Gedrimiene et al. 2020; Khalil et al. 2023), it uses methods such as statistics, data mining, and machine learning for detailed analysis of learning data. This helps monitor student performance and the learning process more effectively, aiding educators in making informed decisions (Fan et al. 2021; Smith 2020; Zhang et al. 2018). Studies (e.g., Han et al. 2021) show the effectiveness of LA in evaluating performance and personalizing learning. Despite these advancements, critical gaps remain in the literature, particularly regarding interdisciplinary collaboration and ethical considerations in LA applications (Gedrimiene et al. 2020; Banihashem et al. 2022; Tahiru et al. 2023). To fully grasp its impact, it is crucial to analyze trends and developments in this field. Tools like bibliometric analysis can identify literature gaps and track important trends in education.

Accordingly, this study sets out to provide a well-structured and systematic account of LA research. First, it outlines the background and key challenges motivating the study. Second, it formulates clear objectives to map publication trends, identify leading countries, institutions, authors, and journals, and to trace thematic and methodological evolutions in the field. Third, it addresses the problem that existing bibliometric reviews are limited in scope, often relying on a single database or covering a narrow time span. To overcome these gaps, this study applies a bibliometric design grounded in both Web of Science and Scopus, while adapting the PRISMA approach to ensure transparency in the selection process. This concise methodological roadmap demonstrates how the analysis is conducted and frames the contribution of the paper.

1.1 The importance of bibliometric analysis of LA in education

Bibliometric analysis is the examination of published works in any field using mathematical and statistical methods (Pritchard and Wittig 1981). It plays a crucial role in the deep understanding of scientific research, to comprehensively evaluate the current state, impact, and potential future directions (Durak et al. 2024). In bibliometric analyses, the number of publications indicates the growth rate of research, while citation and co-citation analyses reveal the most influential works and authors in the field. Keyword analyses identify the core topics that the research focuses on. Journal analyses show which journals are dominant in a specific field, and geographical distribution highlights which regions or countries are

more active. Research trends indicate which topics are on the rise or being overlooked. Network analysis visualizes the relationships between different authors, institutions, and topics.

LA is a discipline that enables data-driven decision-making in educational processes (Bozkurt 2016). The increasing reliance on bibliometric analyses in LA research highlights the need for a systematic evaluation of methodologies, challenges, and evolving research trends (Gedrimiene et al. 2020; Khalil et al. 2023). Bibliometric studies in this field provide numerous advantages to researchers, educational institutions, and policymakers. They can reveal the key topics, methods, and findings in the LA literature, indicating which topics attract more interest and which methods are more widely used. Additionally, they can form the basis for developing strategies to enhance data usage in education. However, previous bibliometric studies have often relied on a single database, limiting their scope and comprehensiveness (Gedrimiene et al. 2020; Dormezil et al. 2019). This study aims to address these gaps by incorporating data from both WoS and Scopus databases.

LA has garnered significant attention from researchers in recent years (Fig. 1), leading to a substantial increase in the volume of studies in the field. The proliferation of research makes it challenging to track developments effectively. Bibliometric analysis offers a comprehensive and systematic approach to evaluate research trends, providing detailed insights through various graphical representations. Despite the significant number of studies conducted in LA, there remains a lack of critical synthesis in areas such as ethical concerns, interdisciplinary research, and emerging applications beyond higher education (Gedrimiene et al. 2020; Sønderlund et al. 2018). To address these gaps and advance the field, this study aims to conduct a comprehensive bibliometric analysis of Learning Analytics (LA) research by utilizing data from both Web of Science (WoS) and Scopus. It seeks to identify key research trends, influential scholars, prominent journals, and institutional collaborations in LA. Additionally, it evaluates the evolution of LA methodologies, highlights emerging

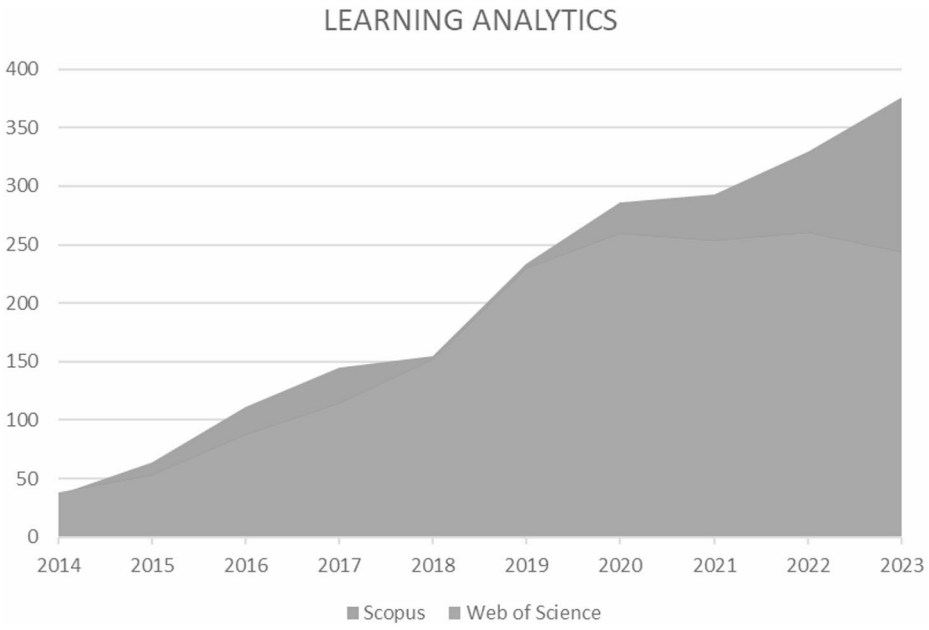

Fig. 1 Number of academic publications on LA from the WoS and Scopus databases

interdisciplinary approaches, and uncovers gaps in ethical considerations and stakeholder involvement in LA research. By doing so, this study contributes to a more structured understanding of the field and provides a reference for future research directions.

Therefore, this study addresses the following research questions through bibliometric analysis:

1. Which countries and institutions are at the forefront of LA research; how are research connections and collaborations formed among countries and institutions?
2. Which journals and authors are the most prolific in this field; what patterns can be observed in citation networks among leading journals?
3. What does the analysis reveal about the nature of author collaborations and the impact of co-citation among prominent researchers in this field?
4. Which topics are most prevalent in LA research, and how are they interconnected, as indicated by the analysis of commonly used keywords?

A key strength of this study lies in its methodological rigor, particularly in the careful selection of keywords and the simultaneous use of two prominent databases, Web of Science (WoS) and Scopus. WoS is renowned for its high-quality scientific publications, while Scopus is recognized as the most comprehensive database worldwide. By analyzing existing systematic reviews, content analyses, and bibliometric studies, this research has developed a tailored keyword pool to ensure the accuracy and relevance of the bibliometric analysis. The combined use of WoS and Scopus not only enhances the reliability and comprehensiveness of the analysis but also provides a broader perspective on global research in the field of LA.

2 Literature review

Chatti et al. (2012) describe a reference model for LA considering four dimensions: data environments, stakeholders, objectives, and methods, which they depict in a graph and represented as what, who, why, and how, respectively (Fig. 2). It allows to categorize LA work in a comprehensive manner. This reference model illustrates the multifaceted nature of LA, encompassing various dimensions such as DataTEL (data from technology enhanced learning) and big data, coupled with indicators and metrics to guide research. In this model, the 'What' dimension pertains to the data and environments utilized in LA, 'Why' refers to the objectives that drive LA activities such as monitoring, prediction, and intervention, and 'How' relates to the techniques like statistics and data mining. The 'Who' encompasses the stakeholders involved, including learners and educators.

However, recent studies (Márquez et al. 2023; Viberg et al. 2020) have pointed out several limitations of the Chatti et al. (2012) model. A key issue is limited adaptability to multimodal data and AI-driven personalization. Additionally, it does not sufficiently address the ethical and privacy concerns that have become increasingly relevant in LA research. Given the rapid technological advancements in AI and learning analytics, newer models have been proposed to address these gaps.

Alternative models, such as the Human-Centered Learning Analytics Framework (Buckingham Shum et al. 2019) and the Ethical Learning Analytics Model (Kitto and Knight 2019), suggest a shift toward stakeholder agency, transparency, and real-time interventions.

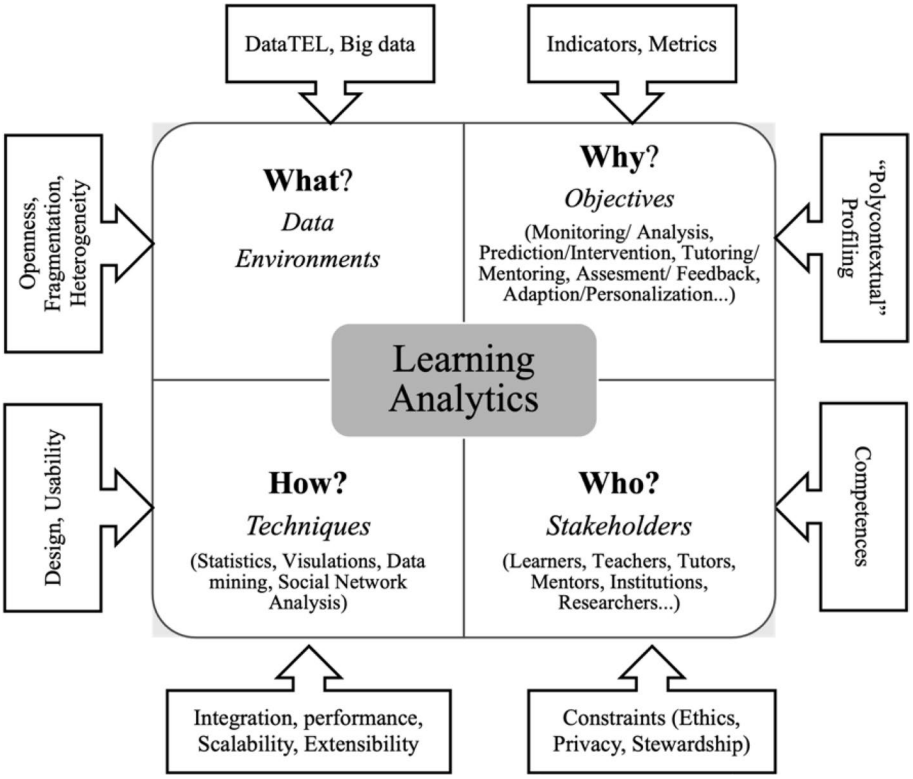

Fig. 2 LA reference model (Chatti et al. 2012)

These models emphasize a broader scope beyond the Chatti et al. framework, aligning with the increasing role of data ethics, student agency, and institutional responsibility in LA research (Márquez et al. 2023). The Human-Centered Learning Analytics Framework prioritizes the involvement of learners and educators in decision-making processes related to data use, while the Ethical Learning Analytics Model incorporates governance structures to ensure fair and responsible analytics implementations.

Moreover, the emerging research trends indicate a shift in LA applications. Recent systematic reviews (Márquez et al. 2023; Khalil et al. 2023) highlight the growing use of predictive analytics, AI-powered adaptive learning, and multimodal learning analytics (MMLA) to improve personalized education. Multimodal learning analytics (MMLA) integrates data from various sources, including physiological sensors, eye tracking, and behavioral analytics, to provide a more holistic understanding of learning processes (Pei et al. 2023). However, gaps remain in interdisciplinary collaboration and the practical implementation of LA at scale (Viberg et al. 2020; Khalil et al. 2023). While AI-driven LA is gaining momentum, concerns regarding algorithmic bias, data privacy, and institutional policies remain significant barriers to adoption.

Our first attempt was to organize the 20 most cited LA studies into categories in Table 1 using the Chatti et al. (2012) reference model. While this categorization provides insights into the dominant themes in LA research, it does not capture the full complexity of con-

Table 1 Categorization of top 20 most cited LA articles based on the LA reference model

		Alignment with LA Reference Model			
Source	Year	What? (Data)	How? (Methods)	Who? (Stakeholders)	Why? (Objectives)
Kizilcec et al.	2017	X	X		X
Gasevic et al.	2015	X		X	X
Zawacki-Richter. et al.	2019	X			X
Gasevic et al.	2016		X		X
Papamitsiou, & Economides	2014	X	X		X
Aldowah et al.	2019	X	X		X
Wong et al.	2019		X		X
Verbert et al.	2014	X	X	X	
Conijn et al.	2017		X		X
Schwendimann et al.	2017	X	X		
You	2016		X		X
Chen et al.	2020	X	X		
Pardo & Siemens	2014			X	X
De Barba et al.	2016			X	X
Williamson	2016	X			X
Jovanovic et al.	2017		X		X
Kuzilek et al.	2017	X	X		
Kinshuk et al.	2016	X	X		
Avella et al.	2016	X	X		X
Marbouti et al.	2016		X		X

X, Indicates that the element of the model is present in the referenced source

temporary LA approaches. For example, ethical considerations and emerging AI-based techniques are often absent in this classification. Therefore, future studies should consider integrating additional frameworks that account for these evolving dimensions.

Among the top 20 most cited articles, "Why" (Objectives) and "How" (Methods) are the most frequently addressed categories. They are followed by "What" (Data). "Who" (Stakeholders) was referred to in only four studies. However, "Who" (Stakeholders) was

referred to in only four studies, suggesting that research often overlooks the human and ethical dimensions of LA. This indicates a strong focus on data and methods within the field, with less emphasis on stakeholders and objectives.

In addition to analyzing the top-cited articles, we compiled a comprehensive summary of all accessible bibliometric analyses, systematic reviews, and related studies conducted within the field of LA (Appendix 1). It is possible to see some key themes emerging from the articles presented in Appendix 1. First, many studies focus on higher education, exploring the role of LA in enhancing feedback practices, predicting student outcomes, and promoting inclusiveness for disabled students (Zhang et al. 2018; Guzmán-Valenzuela et al. 2021; Sønderlund et al. 2018; Tahiru et al. 2023; Banihashem et al. 2022; Khalil et al. 2023). Second, data mining emerges as a crucial area, with studies differentiating it from LA and highlighting its rapid growth on a global scale (Boztaş et al. 2023; Dormezil et al. 2019). Third, the theme of prediction is prevalent, with significant attention given to forecasting student performance and outcomes through machine learning and other predictive interventions (Phillips and Ozogul 2020; Kew & Tasir, 2022). Fourth, there is considerable interest in personalized and self-regulated learning, where studies examine the role of AI in tailoring learning experiences and the development of user-centered LA dashboards (Li et al., 2023; Matcha et al., 2019). Lastly, the multimodal data theme underscores the integration of various data modalities to provide a more comprehensive understanding of learning processes (Pei et al. 2023; Mu et al. 2020). These studies collectively demonstrate a multifaceted approach, blending different aspects of the LA framework to address complex educational challenges in various ways.

When reviewing the table, it is observed that most studies have generally been conducted using a single database. This might limit the scope and depth of the studies. It is also observed that many reviews cover a limited number of articles, which can limit the generalizability of the findings. Additionally, most of the existing studies focus on more specific topics within LA, which can make it impossible to comprehensively address the broad trends and key issues in the field. Moreover, relying on data primarily from 2022 and earlier may not fully capture the latest developments in the rapidly evolving field of LA.

3 Method

In this study, bibliometric analysis was employed to investigate the extensive academic literature related to LA. This section details the methodological framework, the databases utilized, inclusion and exclusion criteria, and the analytical tools used in the interpretation of the data.

3.1 Determination of studies

This bibliometric analysis was conducted using the WoS and Scopus databases. The WoS database is renowned for including high-quality publications, while Scopus is distinguished as the largest academic database. The joint consideration of these two databases ensures access to both high-quality and extensive research outputs, providing a comprehensive overview of the field. Given the differences in indexing criteria between these databases, a

comparative approach was adopted to mitigate potential biases and ensure consistency in the selection of studies.

The initial search returned 2245 records. After removing 417 duplicates, 1828 records remained for screening. In the first stage (title and abstract screening), 1327 studies were excluded because they did not focus on Learning Analytics, belonged to unrelated fields, or were not peer-reviewed journal articles. In the second stage (full-text review), 313 publications were excluded as they were conference papers, editorials, or book chapters, or because they failed to meet language and time-span requirements. Ultimately, 188 articles published between 2014 and 2023 were retained for analysis.

The inclusion criteria required studies to be peer-reviewed journal articles, written in English, and published within the selected ten-year period. Exclusion criteria encompassed grey literature, non-peer-reviewed sources, conference proceedings, and duplicate records across databases. This stepwise procedure ensures both rigor and replicability, reducing potential biases while capturing the most relevant contributions.

Figure 3 presents the data collection methodology, which incorporates a structured approach to bibliometric analyses. While PRISMA is typically associated with systematic reviews, it was adapted in this study to enhance transparency in the selection process, ensuring clear documentation of the inclusion and exclusion criteria. Establishing clear criteria is crucial to maintaining the accuracy and reliability of bibliometric analyses. The figure illustrates these criteria, highlighting the systematic approach used to filter and select the studies included in the analysis.

3.2 Data analysis

Five complementary bibliometric techniques were applied to examine the structural, collaborative, intellectual, and thematic dimensions of the Learning Analytics literature. Bibliographic coupling analysis identified structurally related publications based on shared cited references. Co-authorship analysis examined scientific collaboration by constructing networks of joint authorship across authors, institutions, and countries. Citation analysis evaluated scholarly impact through citation counts normalized across databases. Co-citation analysis identified the intellectual structure of the field by analyzing references frequently cited together. Keyword co-occurrence analysis revealed dominant research themes through clustering of frequently co-occurring keywords after preprocessing and threshold application.

To ensure methodological rigor, VOSviewer and R Studio were employed for data processing and visualization. These tools facilitated the systematic categorization of datasets extracted from the two databases, enabling detailed network visualizations. To enhance data accuracy, preprocessing steps were performed to standardize author names and institutional affiliations, minimizing inconsistencies in the dataset. In addition, synonyms in keywords were merged (e.g., “LA” and “learning analytics”) to ensure conceptual consistency.

The research encompassed five analytical dimensions: bibliographic coupling (identifying related works based on shared citations), co-authorship (mapping collaboration networks), citation (tracking the influence of publications), co-citation (examining how frequently two documents are cited together), and co-occurrence analyses (identifying thematic clusters based on keyword associations), each providing insights into different aspects of scholarly communication. For these analyses, threshold values were applied to

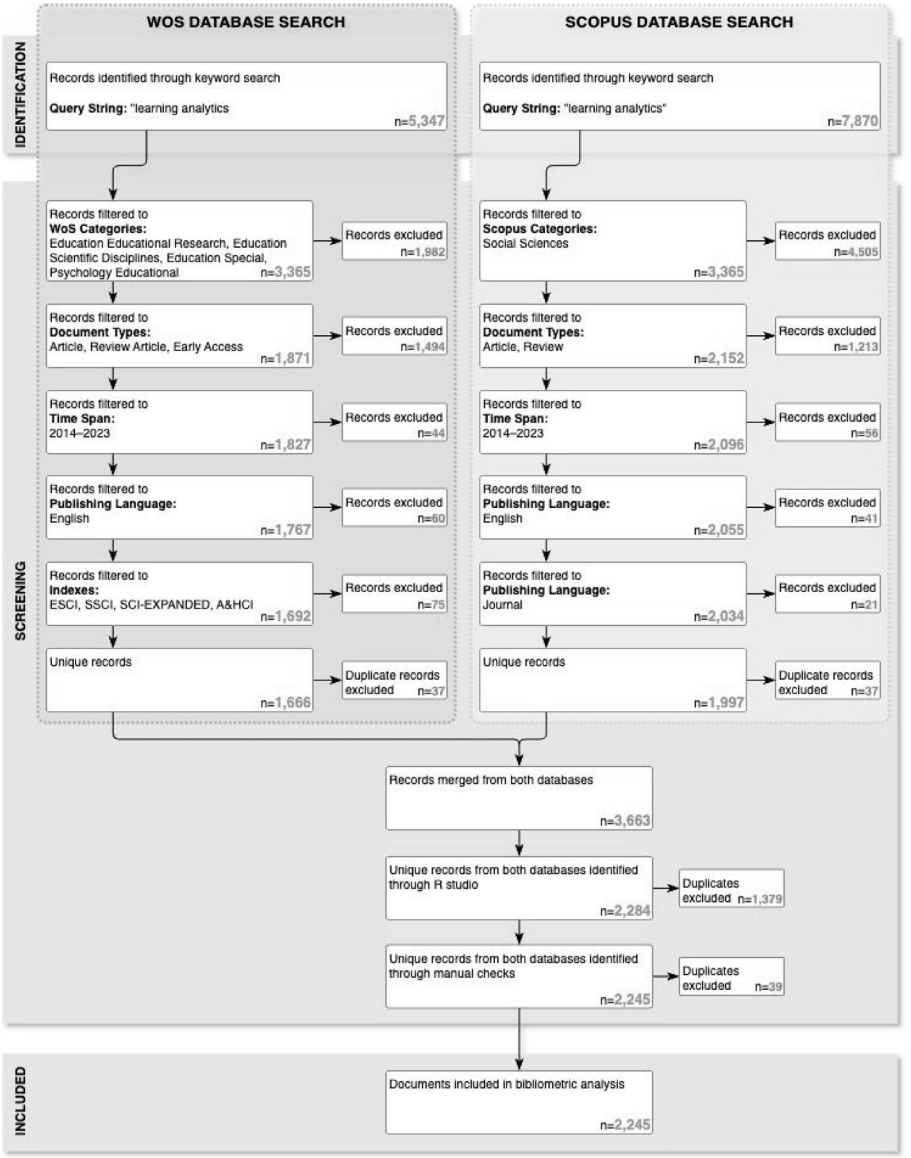

Fig. 3 PRISMA flowchart for bibliometric analysis

strengthen validity: countries, journals, and authors were included if they had at least five documents and 100 citations; for keyword networks, terms occurring fewer than five times were excluded to reduce noise.

All visualizations were generated using VOSviewer (v1.xx) and bibliometrix/biblioshiny in R (v4.xx). Parameter settings such as normalization method (association strength), clustering algorithm (modularity-based clustering), and resolution values were recorded and cross-

checked, allowing replication of the results. Sensitivity analyses with adjusted thresholds yielded qualitatively consistent clusters, further reinforcing the robustness of the findings.

Additionally, parameter settings used in VOSviewer and R Studio were documented to ensure the replicability of the study, aligning with best practices in bibliometric research. Further details on these analyses are provided in the findings section.

3.3 Findings

This section presents the findings in alignment with the research questions.

3.4 Overview of the current state of research

The current LA research is characterized by a substantial body of work, comprising a total of 2245 articles published across 428 distinct academic journals. The field has experienced an annual publication growth rate of 26.9%, reflecting a robust and expanding interest in LA. On average, each article has garnered 15.71 citations, indicating a high level of academic engagement and impact. The total number of contributing authors has reached 4715, with 202 of these articles being single-authored. Notably, only 22.68% of the articles involve international collaboration, underscoring both the significance of the field and the potential for increased global cooperation. While the existing collaboration is a positive indicator, there remains considerable scope to enhance international partnerships and incorporate diverse global perspectives, further advancing the research and application of LA.

3.5 Leading countries and institutions

Country information was extracted from WoS and Scopus databases and visualized on a world map using R Studio. Figure 4 illustrates the distribution of articles by country and the network of international collaboration. Table 2 presents the volume of research and citations on LA across countries.

According to Fig. 4; Table 2, there is a clear visual and statistical representation of the geographic distribution of research papers in the field of LA, indicating a strong concentration of scholarly work from the USA, Australia, Spain, China, and England. The USA leads significantly in both the volume of research (533 papers) and citations (9464), demonstrating its pivotal role in international collaborations, particularly with Canada (34 collaborations), Australia (29 collaborations), and China (29 collaborations). Australia follows with 303 papers and 6570 citations, and Spain with 228 papers and 3148 citations, both contributing significantly to global research efforts. The visualization and data together highlight the interconnected nature of the LA field and underscore the importance of cross-country partnerships in advancing the discipline. Additionally, Scotland, despite a smaller output of 51 papers, achieves a high citation efficiency with 2576 citations, highlighting the quality of research produced in smaller regions.

Figure 5 illustrates the bibliographic coupling among countries through network visualization, revealing the connections among citing publications. This helps track thematic evolution and current advancements in LA. To be included, a country needed at least 5 documents and 100 citations. Out of 158 countries, 45 met this criterion. For these countries,

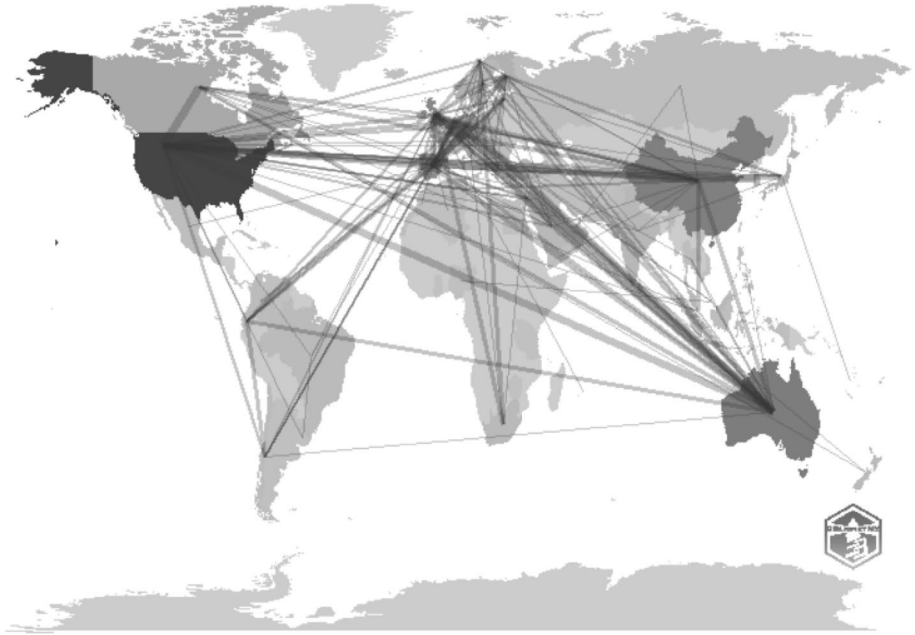

Fig. 4 Scientific production by country and collaboration network. Different shades of blue indicate different productivity rates: dark blue = high productivity, grey = no articles

Table 2 Volumes and citations of research across countries

Rank	Country	Frequency	Citation score
1st	USA	533	9464
2nd	Australia	303	6570
3rd	Spain	228	3148
4th	China	214	2276
5th	England	202	3882
6th	Germany	108	1904
7th	Canada	105	1743
8th	Netherlands	98	2515
9th	Taiwan	89	1789
10th	Norway	70	1190

we calculated the number of publications, citations, and Total Link Strength (TLS), which indicates the shared cited references between countries.

In the bibliographic coupling analysis, which ranks countries by their scholarly connections, the USA, Australia, Spain, England, and China emerge as key nodes due to their strong bibliographic ties. The graph, with color-coded clusters, shows a complex network where thicker lines between nodes represent stronger bibliographic coupling. According to van Eck and Waltman (2014), this indicates that research from these countries often cites similar sources, reflecting their deep scholarly links. The large circles underscore their prominence in global research.

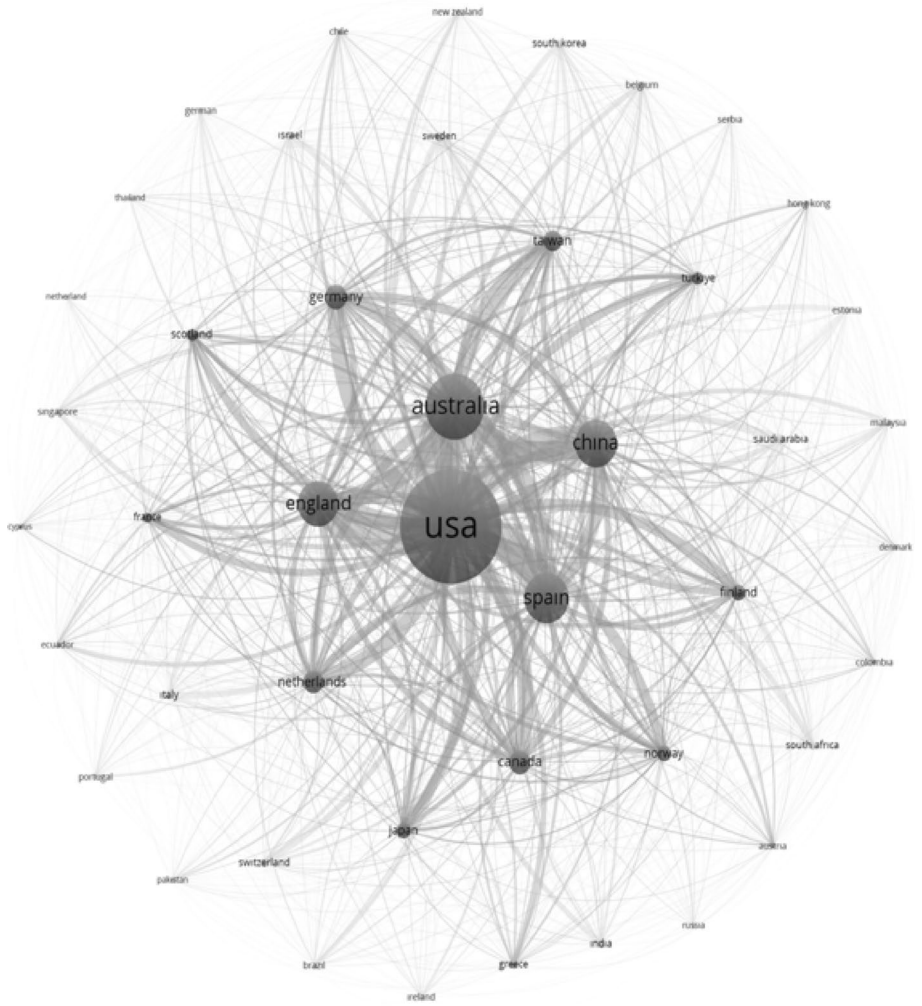

Fig. 5 Bibliographic coupling of the countries

The central cluster features these active countries, which significantly contribute to research volume and form interconnected networks. European nations, particularly, show strong regional collaborations. Notably, the frequent partnerships between Australia and the UK highlight a dynamic bilateral relationship within the LA field.

Figure 6 shows the co-authorship network of countries in LA, based on scholarly output and collaborations. Each circle represents a country, with its size reflecting the number of publications. Lines between circles indicate collaboration intensity, with thicker lines showing more frequent collaborations. Clusters are color-coded to represent similar research areas. The analysis included 45 countries, each meeting the criteria of at least 5 documents and 100 citations.

The bibliometric coupling graph highlights international research collaboration through four clusters. The USA, as a central node, is extensively connected, particularly with China,

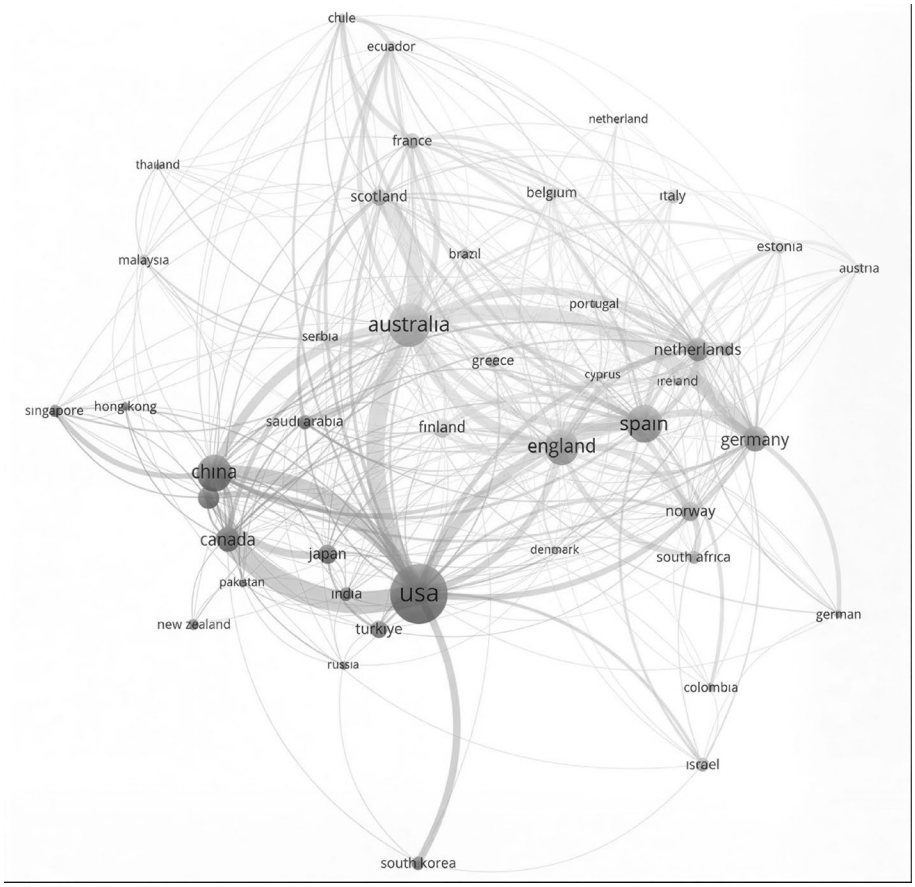

Fig. 6 Co-authorship network of the countries

underscoring its key role in global research networks. Australia also shows strong ties, while Spain and England are notable for their significant partnerships. The clusters illustrate distinct patterns: Cluster 1 includes the USA, China, Canada, and Taiwan, forming a broad network; Cluster 2 connects England and Norway; Cluster 3 links Australia and Scotland; and Cluster 4 groups Germany, the Netherlands, and Spain, reflecting a strong European community. This visualization underscores the complex global collaboration landscape in the LA field.

To understand the LA landscape, it is crucial to evaluate both quantitative contributions and collaborative networks of leading institutions. Table 3; Fig. 7 reveal the significant roles of these institutions by presenting their publication and citation metrics and visually depicting their bibliographic connections.

Table 3 highlights Monash University, Open University, and the University of Edinburgh as leading contributors. Monash University stands out with 76 publications and a citation score of 1564, followed by Open University with 56 publications and 1426 citations, and the University of Edinburgh with 43 publications and the highest citation score of 2407.

Table 3 Number of LA publications and citations of top 10 institutions

Rank	Organization	Number of documents	Citation score
1	Monash University	76	1564
2	Open University	56	1426
3	University of Edinburgh	43	2407
4	University of South Australia	40	1508
5	Kyoto University	31	517
6	University of Technology Sydney	29	641
7	University of Eastern Finland	29	478
8	Beijing Normal University	29	268
9	Central China Normal University	27	391
10	University of Florida	26	466

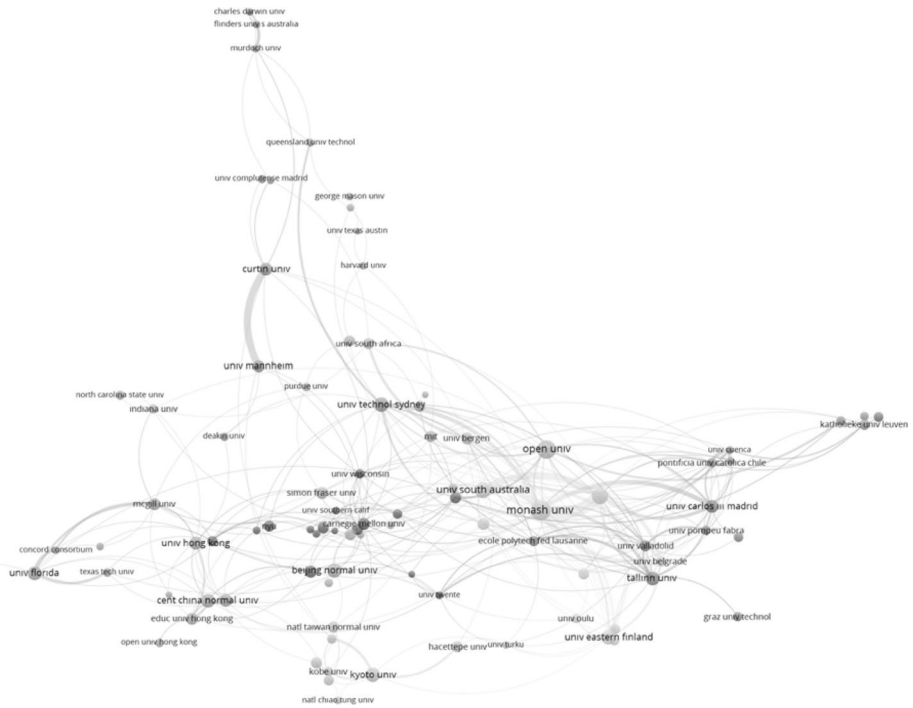

Fig. 7 Co-authorship analysis of institutions

Table 3; Fig. 7 reveal that institutions with high publication rates often form dense networks, suggesting a correlation between prolific output and extensive collaborative engagements.

3.6 Leading journals and authors

The 2245 articles examined appeared in 291 unique journals. When these journals are ranked by their publication count, 147 of them had just one article each. A list of the top 10 journals can be found in Table 4.

Table 4 The 10 most-cited journals regarding LA research between 2014–2023

Journals	NP	NC	TLS
British Journal of Educational Technology (BJET)	104	2658	838
Journal of Learning Analytics (JLA)	154	1754	764
IEEE Transactions on Learning Technology	74	2022	548
Journal of Computer Assisted Learning (JCAL)	68	1603	491
Computers & Education (C&E)	71	2863	446
Internet & Higher Education (I&E)	32	2036	407
Technology Knowledge and Learning (TKL)	52	881	381
Education and Information Technology (EIT)	85	778	369
ET&D- Educational Technology Research and Development	50	860	359
Interactive Learning Environments (ILE)	79	1184	323
Educational Technology & Society (ETS)	49	1320	318

NP, number of publications; NC, number of citations; TLS, total link strength

The table showcases academic journals and their output in terms of publications, citations, and total link strength—a metric reflecting influence and network presence. The BJET stands out for its high citations, indicating its significant impact. JLA leads in publications, showing extensive research activity. C&E, despite fewer publications, has an exceptionally high citation count, pointing to the influential nature of its content.

The citation network map of leading journals, as illustrated in Fig. 8, focus on those with at least 5 articles and 100 citations to ensure the inclusion of publications with significant scholarly impact. This is to evaluate the influence and prestige of journals, reflected by the frequency of citations they receive within the academic community, as a measure of contribution to the field.

Combining insights from the journal table (Table 4) and network visualization (Fig. 8) provides a comprehensive overview of influence and collaboration within the LA context. The JLA and C&E lead in publication output and citation count, respectively. These journals also feature prominently in the network, indicating their significant roles as hubs of scholarly output and impact. Similarly, the BJET stands out for its high citation count and substantial node in the visualization, suggesting its articles are seminal works. Journals like EIT and ILE occupy warmer regions of the network map and exhibit strong TLS values, indicating their centrality and importance. Integrating these datasets underscores the multi-dimensional nature of journal influence, highlighting how high-citation journals often serve as keystones in academic discourse. Additionally, journals with significant TLS values demonstrate extensive interdisciplinary connections and influence across research clusters.

Following the analysis of academic journals, the study provides a ranking of leading authors in the field, considering publication counts, citation numbers, and h-index scores. This multi-dimensional evaluation, outlined in Table 5, emphasizes the notable impact and scholarly presence of these top contributors within the research community.

Table 5 highlights Gasevic as a pivotal figure in LA research, with an h-index of 87, numerous publications, and high citation counts. Rienties, Dawson, and Pardo also stand out for their significant contributions, reflected in their substantial citations and h-index values.

The study then employs co-authorship analysis to explore the broader landscape of intellectual collaboration among researchers. This analysis reveals 16 clusters involving 67 authors in the LA field, as shown in Fig. 9. The first seven clusters exhibit dense collaboration, while the others consist of individual or emerging scholars. Central figures like

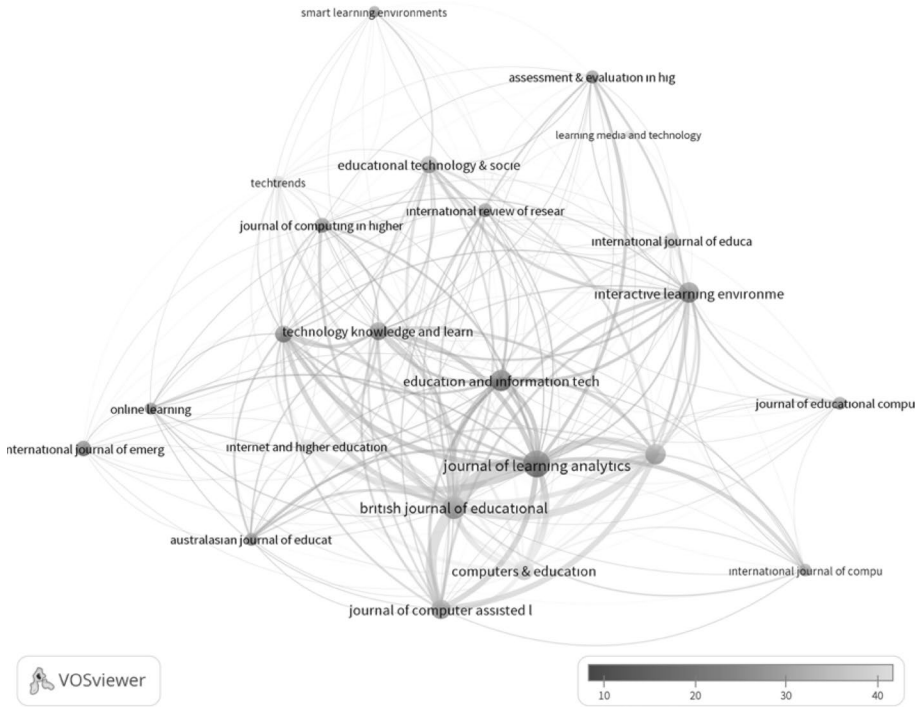

Fig. 8 Citation network map of leading journals

Table 5 Leading authors by the number of publications and citations

Author	NP	NC	h-index (Google Scholar)
Gasevic D	62	2585	87
Saqr M	34	373	25
Ifenthaler D	21	443	53
Rienties B	35	774	65
Prinsloo P	20	222	37
Ogata H	36	481	49
Pardo A	31	1541	53
Siemens G	6	757	64
Ouyang F	20	269	20
Dawson S	21	1518	62

NP, number of publications; NC, number of citations

Gasevic, Pardo, and Dawson demonstrate extensive collaborative ties, with Rienties being particularly influential due to his network connections.

Co-citation patterns explore the impact and connections within this academic community and highlight how authors are linked through shared references, revealing the influential works and ideas that shape the discourse. Figure 10 illustrates the co-citation analysis, showing how key authors, such as Gasevic, Dawson, Ogata, Pardo, and Siemens, are interconnected through frequently co-cited works. This network reflects the collaborative nature

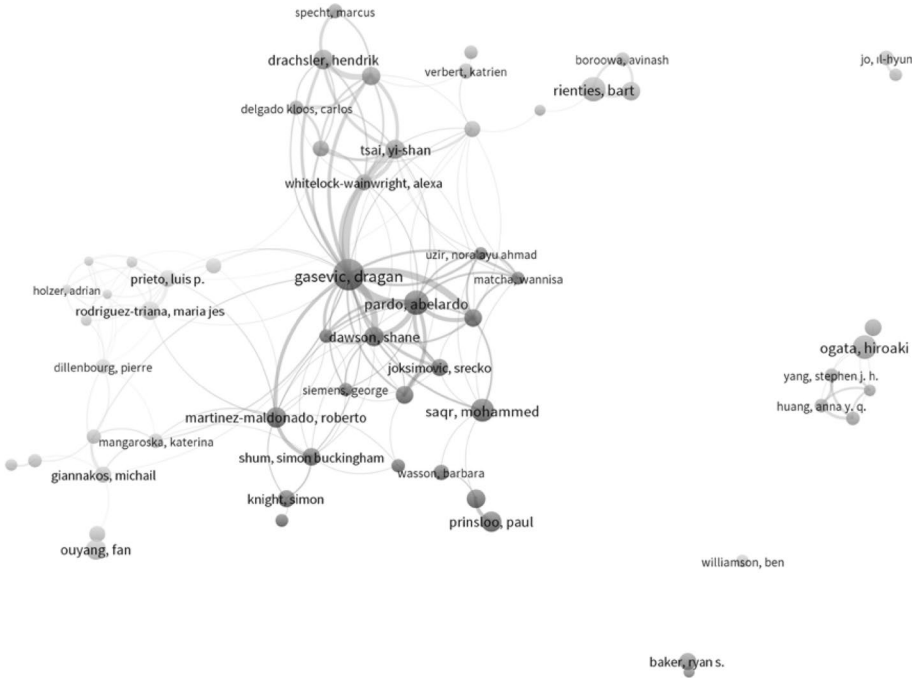

Fig. 9 Co-authorship analysis

of the field, with central figures bridging diverse subfields and methodologies, as indicated by their significant h-indices.

Beyond structural collaboration patterns, these co-authorship clusters also reflect thematic concentrations within the Learning Analytics field. Highly connected clusters involving authors such as Gasevic, Pardo, Dawson, and Rienties predominantly focus on core themes including learning analytics frameworks, predictive modeling, and evidence-based decision-making, as identified in the keyword co-occurrence analysis. In contrast, smaller or emerging clusters tend to concentrate on more specialized topics such as learning dashboards, instructional design applications, and context-specific analytics implementations.

3.7 Analysis of keywords

Co-word analysis is essential for mapping the intellectual landscape and thematic connections in LA research. By examining how keywords frequently co-occur in literature, this method reveals the relationships between ideas, highlights key trends, and identifies potential new research areas. Figure 11 illustrates this with a network of author keywords from the two databases, where larger circles represent common subjects, and yellow nodes indicate popular terms.

At the core of the network, “learning analytics” is the dominant keyword, surrounded by significant related terms like “higher education,” “educational data mining,” “self-regulated learning,” and “machine learning.” This suggests these areas are frequently explored within

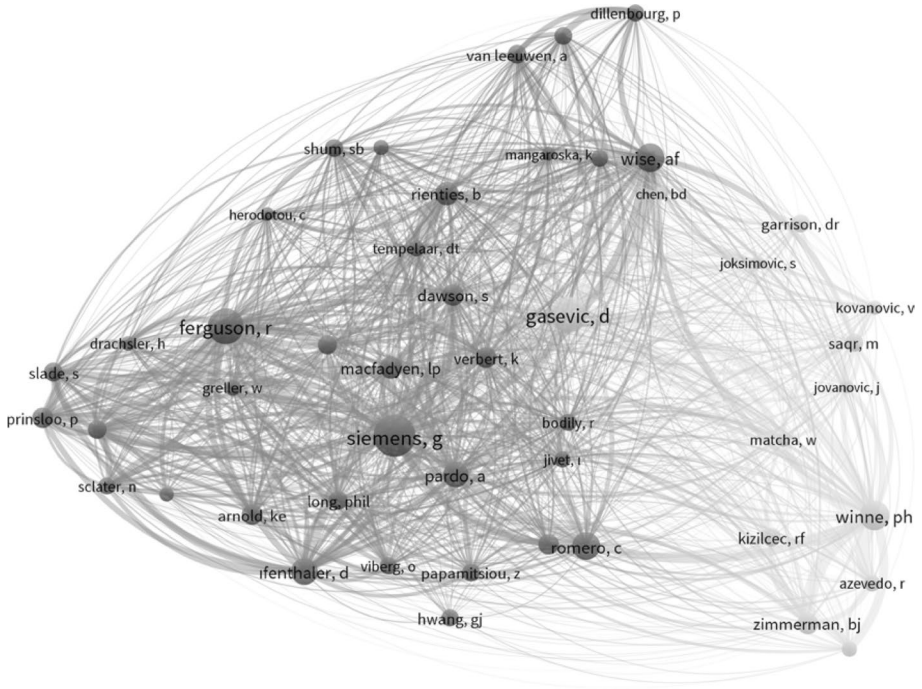

Fig. 10 The most cited authors (co-citation analysis)

LA. Emerging clusters such as "game-based learning" and "mobile learning" point to innovative directions in the field.

The prominence of keywords like "artificial intelligence" and "machine learning," highlighted in yellow, underscores their growing importance in LA, reflecting the integration of advanced AI tools in education. These trends indicate a synergy between technological innovations and LA's application across various educational settings. The increased focus on AI and machine learning also aligns with the demand for data-driven decision-making, personalized learning, and predictive analytics in education, driven by the rapid adoption of general AI platforms since late 2022.

3.8 Thematic analysis

Figure 12 presents the thematic analysis of publications on LA, revealing key insights into current research trends. The upper right quadrant (Q1) showcases the driving (motor) themes, such as "education data mining" and "visualization," which are central to the progression of LA research. Below it, the lower right quadrant (Q4) contains foundational (basic) themes like "learning analytics," "higher education," and "educational data mining," which form the essential building blocks of the field.

The upper left quadrant (Q2) highlights niche themes, including "improving classroom teaching" and "distance education and online learning," which, while specialized, have not yet significantly influenced LA research. The lower left quadrant (Q3) features emerging or

Fig. 11 Analysis of keyword co-occurrence between 2014 and 2023

declining themes, such as "data science applications in education," pointing to topics that are either newly developing or losing relevance.

This thematic map not only underscores the current research trends in LA but also identifies areas for future focus. Strengthening connections between niche themes in Q2 and Q3 with the core themes in Q1 and Q4 could enhance the field's development. Additionally, the evolution of foundational themes in Q4 reflects the dynamic nature of LA, suggesting that even core elements may change over time. Researchers can further enrich LA by integrating niche topics more centrally and expanding their applications in education.

4 Discussion and conclusion

This study provides a detailed bibliometric analysis of the LA field, addressing its rapid growth and increasing academic attention. We began by reviewing the top cited LA studies, categorizing them within an established framework, the LA reference model, and continued to review existing bibliometric and systematic studies on LA, to identify trends and gaps. It also serves as a valuable source for future research, particularly by offering insights into

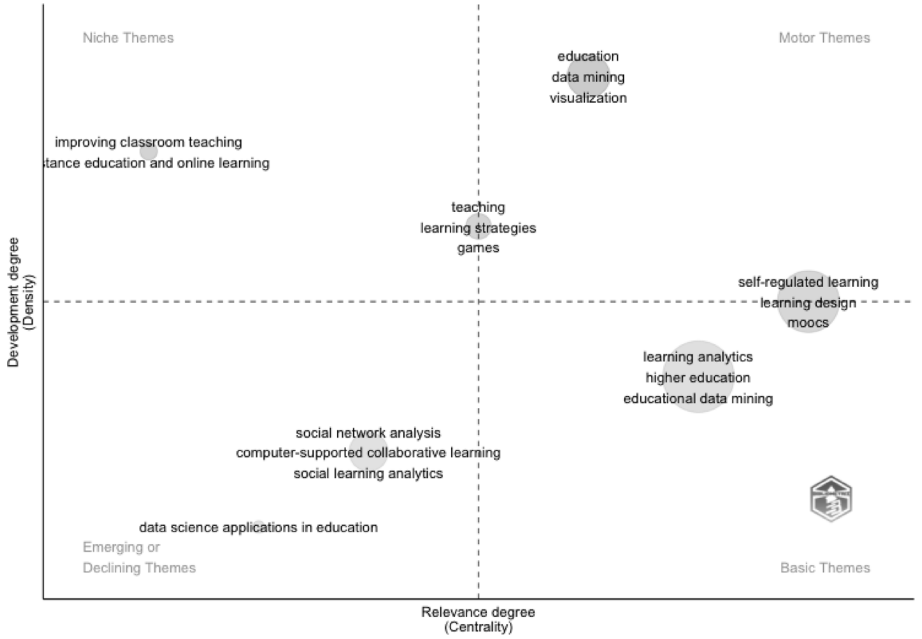

Fig. 12 The thematic analysis of LA publications

past scientific articles on the LA field, which can guide the identification of new research opportunities. Our analysis reveals that while single-authored papers make up a small portion, multi-authored publications (nearly 90%) dominate, highlighting a strong trend toward collaboration, consistent with Azevedo and Azevedo's (2021) findings, indicating a strong tendency among researchers to engage in interdisciplinary and integrated studies, fostering a rich collaborative environment. This trend underlines the importance of international collaborations, which are increasingly significant and account for nearly one-quarter of all papers, emphasizing the growing relevance of global academic cooperation. The field shows a 27% annual growth rate in publications, underscoring the expanding interest and the significance of international collaborations, which account for nearly one-quarter of all papers.

What distinguishes this study is its extensive scope, incorporating data from both WoS and Scopus, providing a broad and more accurate representation of the LA field. This comprehensive approach ensures the findings reflect current trends and offer valuable insights into the field's evolution.

In answer to our first research question, our analysis indicates a sharp rise in publications after 2018, likely driven by the increasing use of AI in education, institutional efforts to enhance educational quality, advancements in educational technologies, and the expansion of international collaborations. Countries like the USA, Australia, Spain, the UK, and China are central to research production and collaboration consistent with previous research (Azavedo & Azavedo 2021; Boztaş, 2023; Chen et al. 2022; Guzman-Valenzuela et al., 2021; Kaban 2023; Pei et al. 2023; Samsul et al. 2023; Talan and Demirbilek 2023; Waheed et al. 2018), with the USA leading potentially due to its strong R&D investment, prestigious universities, and innovation culture (Hebebci 2021; Talan 2021). Australia and Spain's prominence is attributed to significant investments in educational technology and

robust research infrastructures. The growing significance of these collaborations in the LA field underscores the importance of understanding the global dynamics that shape learning analytics research, particularly how regional factors such as educational policies, technological infrastructure, and cultural contexts drive collaboration and influence research outcomes. The intense collaborations between leading countries can generally be linked to strong academic and cultural ties. For instance, the frequent collaborations between Australia and the United Kingdom could stem from shared language and long-standing academic relationships. Additionally, the close collaborations among European countries might be explained by factors such as geographical proximity and research programs supported by the European Union (Chen et al. 2022).

Institutions like Monash University, Open University, and the University of Edinburgh are highlighted for their significant contributions. Monash's document count reflects Australia's active role in LA, while Open University's focus on distance education and the University of Edinburgh's high citation scores demonstrate their influence. Identifying the most active institutions in the field, as done in this study, helps researchers to strategically select collaborations that maximize impact. The absence of top American universities in the rankings is likely due to dispersed research efforts across many institutions. These trends are also noted in previous studies (Azevedo & Azevedo, 2021; Chen et al. 2022; Kaban 2023; Talan and Demirbilek 2023; Vera 2017).

Research question 2 is addressed in the journal analysis, where JLA leads in publication numbers, underscoring its central role, while C&E's high citation count reflects its significant influence in LA. BJET also stands out for its broad impact, with these journals collectively shaping the direction of educational technology studies, a trend aligned with the literature (Chen et al. 2022; Guzman-Valenzuela et al., 2021; Kaban 2023; Phillips and Ozogul 2020; Talan and Demirbilek 2023; Vera 2017). This analysis is essential for recognizing the most influential journals and directing future submissions to platforms that have a significant impact in the field, enhancing research visibility and dissemination.

In response to research question 3, key authors like Gasevic, Pardo, Dawson, and Rienties are noted for their high publication and citation numbers, reflecting their substantial impact. Their collaborations enhance the field's breadth and effectiveness, with their prominence on the broader aspects of LA aligning with other studies (Azevedo & Azevedo, 2021; Kaban 2023; Phillips and Ozogul 2020; Talan and Demirbilek 2023; Vera 2017). Such bibliometric analyses are instrumental in identifying leading authors and key contributors in the field, which is vital for institutions and journals looking to recruit reviewers or establish collaborations. Studies exploring more specific dimensions of LA might highlight different authors, reflecting the diverse range of expertise within the field.

Finally, addressing research question 4, keyword co-occurrence analysis highlights core terms like "higher education" and "machine learning" as central to LA research. Emerging terms like "artificial intelligence" and "educational data mining" indicate evolving trends in technology application within education (Durak et al. 2025). Similarly, the presence of terms related to "e-learning" and "game-based learning" suggests a diversification of focus areas, reflecting the field's adaptation to innovative educational practices. Comparable findings regarding keyword trends have been observed in past research (Kaban 2023; Samsul et al. 2023; Waheed et al. 2018; Zhang et al. 2018). Importantly, when comparing the two time intervals (2014–2018 and 2019–2023), an evolution is observed: earlier research was dominated by keywords such as "prediction," "feedback," and "student performance," reflecting

the initial focus on monitoring and outcome forecasting, whereas the later period increasingly featured terms like "artificial intelligence," "multimodal learning analytics," and "ethics." This temporal shift mirrors the rapid diffusion of AI technologies, growing attention to complex data environments, and heightened sensitivity to responsible use, showing how the field of LA has moved from foundational applications toward more advanced, interdisciplinary, and ethically conscious directions.

The thematic analysis divides research themes into four quadrants, aiding strategic planning. This quadrant-based approach is particularly useful in academic settings to align research with evolving knowledge bases. Critical themes like "education data mining" and "visualization" drive LA research, while foundational subjects like "learning analytics" and "higher education" support ongoing development. The second quadrant contains specialized but less impactful themes like "improving classroom teaching" and "online learning," with potential for future significance. The third quadrant features dynamic themes such as "data science applications in education," indicating evolving or waning areas of focus. Such thematic analyses highlight current research focal points while also identifying areas that may require more attention or offer opportunities for innovation, thereby ensuring a balanced and comprehensive research agenda.

Based on the findings of this study, several actionable recommendations can be derived to enhance research and practice in the LA field. Firstly, given the strong trend toward multi-authored and internationally collaborative publications, it is crucial to foster and support interdisciplinary and cross-border research partnerships, which are shown to drive innovation and advance the field. Institutions and funding bodies should prioritize and incentivize collaborative projects that involve diverse teams, as these are more likely to result in impactful research. Additionally, considering the rapid increase in LA publications post-2018, particularly in response to AI integration in education, academic institutions should focus on expanding research that explores the intersection of LA and emerging technologies like AI, educational data mining, and machine learning. This can help to further harness the potential of these technologies in educational settings. In addition, recognizing the increase in publication trends helps institutions and researchers anticipate future research demands and allocate resources more effectively. Moreover, the prominence of leading countries such as the USA, Australia, and Spain suggests that regional collaborations and networks should be strengthened to share best practices and drive global innovation in LA. Finally, the significant contributions from institutions like Monash University, Open University, and the University of Edinburgh indicate the importance of supporting centers of excellence within the field, as these institutions play a key role in advancing research and shaping the future direction of LA. Identifying leading institutions also helps researchers and practitioners focus on establishing connections with these centers, further enhancing their own research and development initiatives.

When considering the LA reference model, it is important for future research to pay more attention to the 'Who' (stakeholders) dimension, which has been particularly underrepresented, as well as the 'What' (data environments) dimension, though to a lesser extent. Addressing these gaps can guide future research to be more inclusive of different perspectives and contexts, thereby enriching the field. Collaborative research should extend beyond data and methods to include a deeper understanding of the stakeholders involved and the data environments in which LA practices are situated. Expanding research into emerging technologies like AI should involve not only identifying key stakeholders but also examining the

specific data environments that inform their integration. This approach also encourages the exploration of different contexts and environments in which educational technologies are applied, providing a broader understanding of their impact and effectiveness.

While bibliometric analysis provides a valuable macro-level understanding of research trends, collaboration patterns, and institutional contributions, it does not capture the lived experiences, perceptions, and challenges faced by stakeholders in the LA field. Therefore, future research should integrate qualitative approaches, such as expert interviews, focus groups, and case studies, to complement bibliometric findings with deeper contextual insights. By incorporating mixed-method approaches that blend bibliometric analysis with qualitative and user-centered research, scholars can ensure a more holistic examination of LA's impact, fostering actionable insights that extend beyond publication trends.

Our study also highlights several future research directions that are essential for advancing the LA field, particularly in areas where current research is relatively underdeveloped. Firstly, this involves conducting global comparative analyses of LA research through bibliometric studies, which would provide a broader understanding of regional trends and collaborations, as well as reveal how different regions or contexts are addressing similar challenges, thereby offering new insights and opportunities for collaboration. In addition, examining LA's application across educational levels should ensure that these efforts align with the "Who" and "What" aspects of the reference model. Furthermore, interdisciplinary analysis could reveal how integrating these dimensions enhances the effectiveness of LA. Another recommended direction is the exploration of emerging technologies such as blockchain and augmented reality in LA to evaluate their potential impact and innovation. Disciplinary and interdisciplinary approaches should continue to be supported to drive innovation in the use of emerging technologies in education. Moreover, evaluating LA-driven interventions in educational settings is essential to identify successful applications and areas for improvement. Evaluating LA-driven interventions should focus on aligning these interventions with relevant stakeholders and data environments. Finally, combining bibliometric and content analyses of AI and LA can help uncover significant trends and intersections within these rapidly evolving fields.

4.1 Limitations of the study

While this study provides a comprehensive bibliometric analysis of LA, certain methodological and scope-related constraints should be acknowledged. These limitations may impact the generalizability of findings and suggest areas for further exploration. The key limitations are as follows:

- While this timeframe captures the most recent developments in Learning Analytics (LA), it may exclude earlier foundational studies that contributed to the field's initial development.
- The study does not include other academic databases such as Google Scholar, IEEE Xplore, or ERIC, which may contain additional relevant studies. This limitation may introduce database bias, as WoS and Scopus primarily index high-impact journals and may underrepresent emerging or regional research.
- Citation counts and co-citation analysis do not necessarily reflect research quality or impact, as highly cited papers may be controversial rather than influential. Self-cita-

tions and institutional citation networks may skew the results, favoring certain research groups or geographical regions.

- While the study highlights strong academic collaborations between countries, it does not account for policy influences, funding structures, or institutional strategies that shape these partnerships.
- The study does not include preprints, reports, or non-indexed conference papers, which may contain early-stage research and emerging trends in LA.

Appendix 1

Bibliometric and review studies in the field of LA

Publication title	Author(s)	Database	NRP	NC	Highlights
Academic development of multimodal learning analytics: a bibliometric analysis	Peia et al. (2023)	Scopus, WoS, IEEE Xplore Digital Library, ACM Digital Library and ScienceDirect	194	11	Examined multimodal LA, highlighting the use of multiple data modalities to characterize learning processes.
Bibliometric Analysis of Research on Learning Analytics Based on Web of Science Database	Talan and Demirbilek (2023)	WoS	659	7	Analyzed publication trends in LA, showing the evolution based on bibliometric indicators.
Education big data and learning analytics: a bibliometric analysis	Samsul et al. (2023)	Scopus	250	0	Explored education big data and its impact on enhancing LA practices.
A bibliometric analysis of the learning analytics application in the education	Vera (2017)	Scopus, IEEE Xplore	0	86	Highlighted the necessity of adapting complex data analytics algorithms for use by educators in educational settings.
Analysis and modeling the domain of open educational resources from learning analytics perspective	Ivanova et al. (2020)	Scopus	2500	2	Reviewed the domain of Open Educational Resources through LA to outline current achievements and future trends.
Multimodal Data Fusion in Learning Analytics: A Systematic Review	Mu et al. (2020)	Scopus, WoS, ProQuest, ERIC, EdITLib, ScienceDirect, PubMed, Sage Journal Online, IEEE Xplore digital library, ACM Digital Library, Springer, and Google Scholar	708	50	Systematically reviewed multimodal data integration in LA, presenting a model for understanding data types and fusion methods.

Publication title	Author(s)	Database	NRP	NC	Highlights
Learning Analytics Research in Relation to Educational Technology: Capturing Learning Analytics Contributions with Bibliometric Analysis	Phillips and Ozogul (2020)	WoS	90	33	Found three major research clusters within LA, with significant focus on predicting student outcomes.
A decade of learning analytics: Structural topic modeling based bibliometric analysis	Chen et al. (2022)	WoS, Scopus, ACM, ERIC, and Google Scholar	3900	11	Investigated the thematic structure of LA research, focusing on classroom applications and innovations.
Mapping the study of learning analytics in higher education	Zhang et al. (2018)	WoS	1995	35	Summarized the development of LA in higher education, emphasizing technological innovations.
Learning analytics in higher education: a preponderance of analytics but very little learning?	Guzmán-Valenzuela et al. (2021)	WoS, SciELO	385	63	Discussed the focus shift needed in LA towards more learning-centric approaches.
Learning Analytics: a bibliometric analysis of the literature over the last decade	Azavedo & Azavedo (2021)	WoS	3147	5	Analyzed the evolution of LA over a decade, identifying key research topics and players
Artificial intelligence in personalised learning: a bibliometric analysis	Li and Wong (2023)	Scopus	1005	2	Reviewed the role of AI in personalized learning, identifying trends and contributions to the field.
A bibliometric analysis of Educational Data Mining studies in global perspective	Boztaş et al. (2023)	WoS	626	0	Explored educational data mining from a global perspective, highlighting its rapid growth and evolving themes
Visualization analysis of learning analysis research in international education during the past decade	Ang & Ren (2020)	WoS	200	0	Analyzed LA research trends in education, identifying high-yield countries and institutions.
A bibliometric perspective of learning analytics research landscape	Waheeda et al. (2018)	Scopus	2811	86	Examined the research landscape of LA, suggesting its integration with smart education systems.
An Examination of the Studies on Learning Analytics: A Bibliometric Mapping Analysis	Kaban (2023)	WoS	1590	0	Created a bibliometric map of LA studies, detailing influential research trends.
The efficacy of learning analytics interventions in higher education: A systematic review	Sønderlund et al. (2019)	MEDLINE; Psychology and Behavioral Sciences Collection, SCOPUS, Sciencedirect, IEEE Explore, ACM Digital Library, dblp	11	204	Reviewed interventions based on LA, focusing on their effectiveness in higher education.

Publication title	Author(s)	Database	NRP	NC	Highlights
Learning Analytics in Online Learning Environment: A Systematic Review on the Focuses and the Types of Student-Related Analytics Data	Kew & Tasir (2022)	ACM Digital Library, LearnTechLib, ERIC, International Forum of Educational Technology & So Fig. 12. The thematic analysis of LA publications ciety, ScienceDirect, Wos, Scopus, Society for Learning Analytics Research (SoLAR) and SpringerLink	34	54	Reviewed LA applications in online environments, emphasizing predictive interventions.
Machine Learning-based Predictive Systems in Higher Education: A Bibliometric Analysis	Tahiru et al. (2023)	Scopus	72	1	Reviewed Machine Learning-based predictive systems in higher education, detailing significant contributions and research trends.
Differentiating between Educational Data Mining and Learning Analytics: A Bibliometric Approach.	Dormezil et al. (2019)	Scopus	1952	19	Differentiated between Educational Data Mining and LA through keyword analysis, identifying core research themes.
Artificial Intelligence and Learning Analytics in Teacher Education: A Systematic Review	Salas-Pilco et al. (2022)	WoS	30	34	Systematically reviewed AI and LA in teacher education, analyzing their integration and impact.
A Systematic Review of Empirical Studies on Learning Analytics Dashboards: A Self-Regulated Learning Perspective	Matcha et al. (2019)	ACM Digital Library, IEEE, Springer-Link, Science Direct, and Wiley. Google Scholar	29	327	Reviewed LA dashboards from a self-regulated learning perspective, proposing a new model for user-centered systems.
Model-Based Learning Analytics for a Partnership of Teachers and Intelligent Systems: A Bibliometric Systematic Review	Pishtari et al. (2023)	CM, Aisel, İEEE XPLORE, ScienceDirect, Scopus, SpringerLink, WILEY, Google scholar	276	1	Reviewed model-based LA, emphasizing the partnership between teachers and intelligent systems.
A systematic review of the role of learning analytics in enhancing feedback practices in higher education	Banihashem et al. (2022)	WoS, Scopus, ERIC, IEEE	46	48	Mapped LA implementations to enhance feedback practices in higher education, proposing a conceptual framework.
Learning analytics in support of inclusiveness and disabled students: a systematic review	Khalil et al. (2023)	Scopus, WoS	26	10	Reviewed LA' role in promoting inclusiveness and support for disabled students.

NPR, number of publications reviewed; NC, number of citations

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Declarations

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