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MAPPING RESEARCH TRENDS IN TECHNOLOGY-ENHANCED L2 WRITING IN EFL CONTEXTS: A BIBLIOMETRIC ANALYSIS

(Research Article)

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Abstract

This study presents a comprehensive bibliometric and science mapping analysis of research on technology-enhanced second language (L2) writing in English as a Foreign Language (EFL) contexts. Although digital tools and artificial intelligence (AI) have increasingly influenced language education, a systematic understanding of research trends, intellectual structures, and thematic developments in L2 writing remains limited. To address this gap, a dataset of 221 articles published in Social Sciences Citation Index (SSCI)-indexed journals between 2010 and April 2024 was analyzed using VOSviewer and CiteSpace. The findings reveal a steady increase in research output, with major themes centering on automated writing evaluation (AWE), collaborative writing, digital writing environments, and feedback practices. Co-occurrence, co-citation, and burst analyses demonstrate the evolution of thematic clusters and the growing integration of pedagogical, linguistic, and technological perspectives. Emerging topics such as learner autonomy, data-driven learning, and AI-assisted writing tools indicate a shift toward more adaptive, personalized, and learner-centered approaches to writing instruction. Despite these developments, the findings suggest a continuing need for theoretically informed and interpretive research that can better connect innovation with pedagogical practice. Unlike previous reviews that focused on specific journals, technologies, or empirical studies, this study provides a comprehensive mapping of SSCI-indexed research over a fourteen-year period through the combined use of VOSviewer and CiteSpace. By identifying influential contributors, major research themes, and emerging directions, the study offers a valuable reference for researchers and practitioners and proposes a future research agenda for technology-enhanced L2 writing.

Keywords: L2 writing, bibliometric analysis, citation patterns, theme clusters, EFL.

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1. Introduction

The field of second language (L2) writing emerged in the 1950s and has grown substantially since the 1990s, evolving into a well-established and multidimensional area of research (Silva, 2016). Writing is a complex cognitive activity that requires the integration of multiple strategies and sources of information (Hayes, 1996; Hyland, 2003). Within this field, collaborative writing refers to the process in which two or more learners jointly produce a single text. Over the past two decades, collaborative writing and peer feedback have attracted considerable attention in second language acquisition research. Studies grounded in sociocultural theory suggest that interactions among peers or between experts and novices can scaffold learning and support writing development (Li & Zhang, 2023).

The rapid development of technology has further transformed L2 writing instruction. Increasing attention has been given to the use of innovative technologies to support writing development (Howell et al., 2021; Williams & Beam, 2019). Within the framework of Computer-Assisted Language Learning (CALL), technology-enhanced collaborative writing (TECW) has emerged as an important research area. TECW involves learners collaboratively producing texts through digital platforms and tools (Storch, 2011). Technologies such as wikis and Google Docs provide flexible environments that facilitate collaboration, interaction, and feedback (Zhang & Zou, 2022). Wikis, including Wikispaces, PBworks, and Wetpaint, have been widely investigated as collaborative writing tools in previous studies (Chao & Lo, 2011; Elola & Oskoz, 2010; Lin & Yang, 2011).

More recently, advances in artificial intelligence (AI) and natural language processing have led to the development of Automated Writing Evaluation (AWE) systems. These systems automatically evaluate written texts and provide feedback to support writing development. Automated written feedback (AWF), commonly delivered through AWE systems, has become increasingly prominent in language education (Burstein et al., 2020). Previous studies have examined a wide range of technology-based writing tools, including word processors such as Microsoft Word and Google Docs, intelligent tutoring systems such as Writing Pal, and online writing assistants such as Grammarly (Ranalli & Yamashita, 2022).

In parallel with empirical research, several review studies have examined technology-enhanced language learning and writing. For example, Hung et al. (2018) reviewed 50 studies on digital game-based language learning published between 2007 and 2016, analysing research methods, digital game types, learner characteristics, and learning outcomes. Hussein (2015) conducted a content analysis of 103 articles published in *Teaching English with Technology* between 2008 and 2013, focusing on publication characteristics, participant profiles, research methods, and data collection procedures. Similarly, Riazi et al. (2018) reviewed 272 empirical studies published in the *Journal of Second Language Writing* between 1992 and 2016, examining research contexts, participants, theoretical orientations, and methodologies. Previous reviews have also identified journals such as *Computer Assisted Language Learning*, *Language Learning & Technology*, and *ReCALL* as major contributors to technology-related language learning research (Chen et al., 2018).

Several review studies have examined technology-enhanced language learning and writing from different perspectives. For example, Hung et al. (2018) focused on digital game-based language

learning, whereas Hussein (2015) and Riazi et al. (2018) analysed publication trends, research contexts, and methodological characteristics. Collectively, these reviews have highlighted the growing importance of technology in language learning and identified major publication outlets in the field (Chen et al., 2018). More recently, Sun and Lan (2023) examined L2 writing research published in leading peer-reviewed journals, including the Journal of Second Language Writing, Applied Linguistics, The Modern Language Journal, TESOL Quarterly, and Language Teaching Research. Their review also incorporated additional sources such as Google Scholar, annual reviews of L2 writing scholarship, and annotated bibliographies.

Despite these contributions, comprehensive bibliometric investigations of technology-enhanced L2 writing remain limited. Existing reviews often focus on specific journals, empirical studies, or particular technologies. To address this gap, the present study conducts a bibliometric analysis of technology-enhanced L2 writing research indexed in the Web of Science database between 2010 and April 2024. Unlike previous studies, this research includes all article types, applies a rigorous data-cleaning procedure, and employs both VOSviewer and CiteSpace for data analysis. The combined use of VOSviewer and CiteSpace allows both network visualization and the identification of emerging trends, providing a more comprehensive understanding of the field. By identifying major research themes, emerging trends, influential authors, highly cited publications, and leading journals, this study aims to provide a comprehensive overview of the development of technology-enhanced L2 writing research over the last decade. The findings may inform researchers, language educators, and curriculum developers about emerging directions in technology-enhanced L2 writing, particularly the growing role of AI-assisted writing tools and automated feedback systems in language learning.

The present investigation is guided by the following research questions:

1. What are the dominant themes and trends in the use of technology to enhance L2 writing?
2. Which key authors, documents and countries have made major contributions to the field of technology-enhanced second language (L2) writing?
3. What are the emerging and promising areas for future research in the domain of technology enhanced L2 writing?

2. Method

2.1. Research design

This study utilises bibliometric analysis to examine advancements in the field of technology in language education, specifically focusing on its use in L2 writing. The data were obtained from the Web of Science (WoS) database. The reason for selecting this particular database is its widespread recognition and good quality. It encompasses a wide spectrum of academic literature and has been often utilised in previous review studies, such as the one conducted by Zou et al. (2021). This database is well recognized and extensively utilized as a library resource (Kartal & Yeşilyurt, 2024; Roemer & Borchardt, 2015; Zhang, 2020).

2.2. Data collection

In the study, the journals were selected based on three criteria: (a) their relevance to technology-enhanced language learning and writing research, (b) their academic impact and visibility, as reflected by a minimum h5-index threshold, and (c) their frequent inclusion in previous review and bibliometric studies in the field. In addition, ReCALL was included because of its well-established reputation as a leading journal in Computer-Assisted Language Learning (CALL) and technology-enhanced language education, despite not being listed within the selected Google Scholar category.

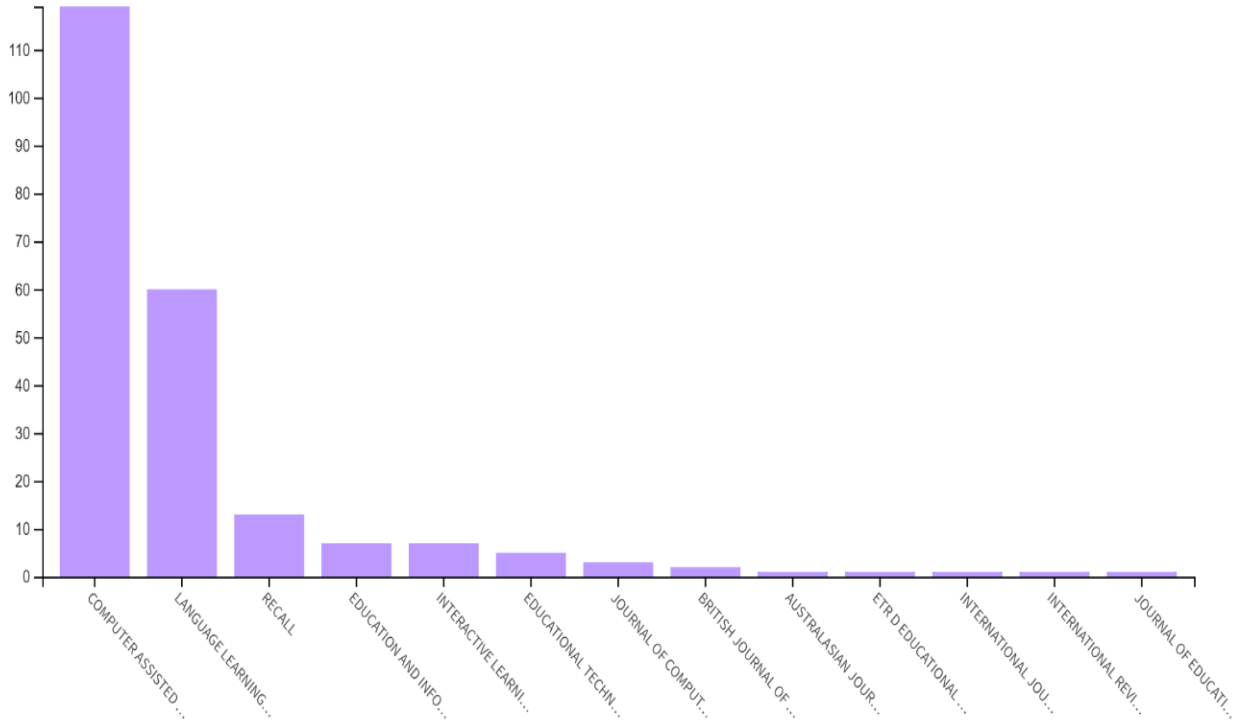

Figure 1. Top Publications in the subcategory of Educational Technology

As illustrated in Figure 1, 19 journals were selected from the Educational Technology category in Google Scholar to identify research related to technology-enhanced L2 writing. The selection of these journals ensured broad coverage of influential publications that have significantly contributed to the development of technology-enhanced L2 writing research.

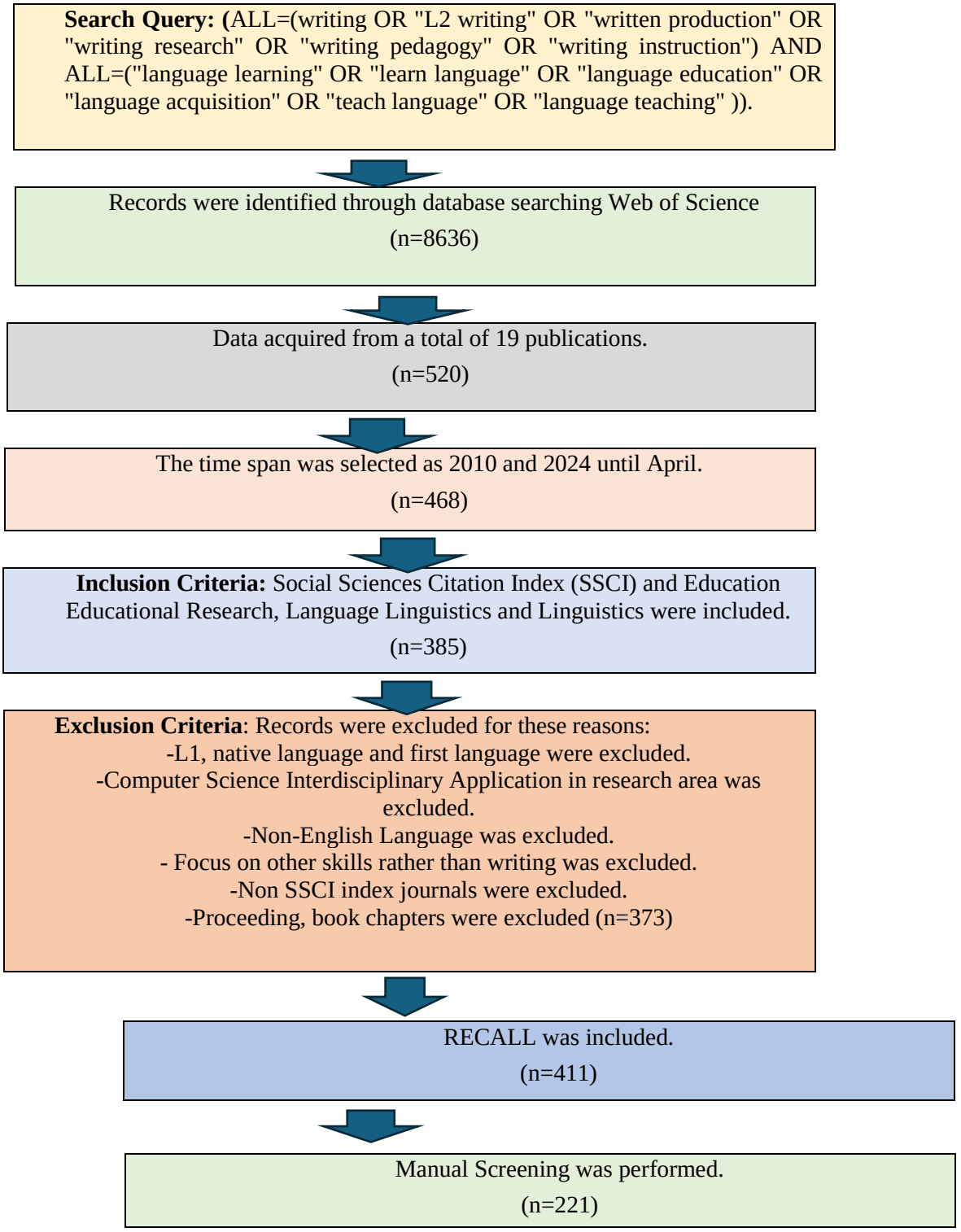

Figure 2. PRISMA flow diagram.

As illustrated in figure 2, we developed two sets of keywords to search the literature: (1) The keywords used in this research to identify relevant literature on L2 writing with technology were developed with the understanding that not all on L2 writing employ the keyword "writing." Consequently, relevant writing-related keywords were developed as a combination of other keywords that have been used in other systematic or scoping reviews in the domain (Chong & Reinders, 2022; Kalyaniwala & Ciekanski, 2021).

Other related keywords (2) “learning language” OR “teaching language” research was used to narrow the search results to studies related to the teaching and were also added as a separate row in the WoS search database to ensure that the studies were all connected to L2.

These terms were chosen to capture the overview of the domain: **(**ALL= (writing OR "L2 writing" OR "written production" OR "writing research" OR "writing pedagogy" OR "writing instruction") AND ALL= ("language learning" OR "learn language" OR "language education" OR "language acquisition" OR "teach language" OR "language teaching")).

To enhance the validity of the search strategy, the search terms were developed and refined based on keywords frequently reported in previous systematic reviews and review studies on L2 writing and technology-enhanced language learning (Chong & Reinders, 2022; Kalyaniwala & Ciekanski, 2021). The retrieved records were subsequently examined through title and abstract screening to verify their relevance to the scope of the study. In addition, the inclusion and exclusion criteria were iteratively applied throughout the screening process to ensure that only studies directly related to technology-enhanced L2 writing in EFL contexts were retained for analysis.

The original search on the WoS database produced 8636 results. In order to guarantee the pertinence and precision of the data, many filters were employed. Data was acquired from a total of 19 publications. There were total of 520 results. A total of 468 articles published between 2010 and 2024 until April were considered. Document type was selected as article which was 435 results. Finally, after considering just articles that are included in the Social Sciences Citation Index (SSCI), there were a total of 385 publications that were relevant. Additional improvement was achieved by specifically choosing articles from 3 categories in the Web of Science (WoS) database that are relevant to the research topic: Education Educational Research, Language Linguistics and Linguistics.

Computer Science Interdisciplinary Application in research area was excluded. Consequently, the pool of articles was reduced to 373 after the selection of these categories. At the end of search, we added RECALL which encourages the use of technology for the learning and teaching of languages. The result was 411.

The analysis was restricted to English-language publications indexed in the Social Sciences Citation Index (SSCI). English was selected because it is the dominant language of international scholarly communication in the fields of applied linguistics, language education, and educational technology. Restricting the dataset to English-language publications also ensured consistency in keyword, citation, and co-occurrence analyses. Furthermore, SSCI-indexed journals were selected because they represent high-quality, peer-reviewed research outlets with established academic impact and international visibility. This decision enhanced the reliability

and comparability of the dataset and enabled the identification of influential publications and emerging research trends within the field.

Nevertheless, this selection criterion may have excluded relevant studies published in other languages or indexed in other databases. Therefore, the findings should be interpreted as representing the SSCI-indexed segment of technology-enhanced L2 writing research rather than the entire body of global scholarship on the topic.

A meticulous manual screening was performed to ensure the correctness and relevance of the chosen articles. This involved doing a thorough examination of the title, abstract, and research questions/hypotheses of each publication, with a specific focus on their pertinence to L2 writing with technology. Articles with unclear relevance using the criteria for inclusion and exclusion outlined in Figure 2 were carefully reviewed and when uncertainty arose regarding the eligibility of a publication, consultation with an experienced researcher was undertaken to reach a consensus decision. This was done to ensure that the selected data were directly related to technology enhanced L2 writing in the context of English as a Foreign Language (EFL). Following the elimination process, we successfully decreased the total number of articles from 411 to 221.

Data underwent a detailed cleaning process to ensure accuracy and consistency. This included creating thesaurus files for integration into VOSviewer, a bibliometric software tool used for this study. Terms like "Computer-assisted language learning" were standardized to "CALL" and variations such as "Second language writing", "EFL writing" "Foreign Language Learning" and "English Language Learning" were uniformly coded as "L2 writing. "Data driven learning were standardized to "ddl". The singular and plural versions of nouns such as blog/blogs, corpus/corpora, and wiki/wikis were merged.

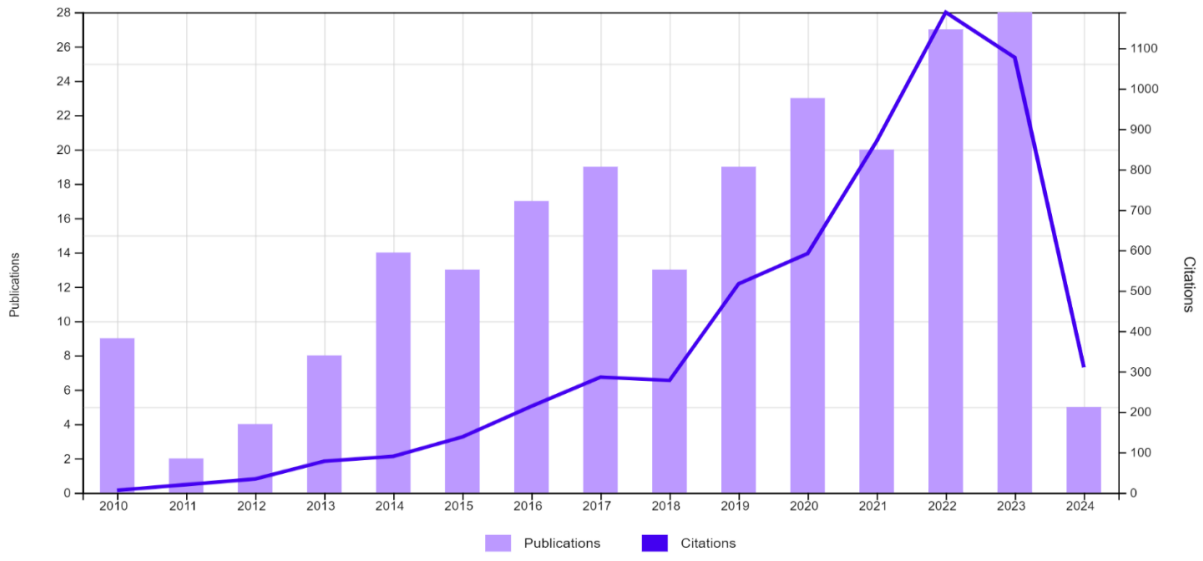

Figure 3. Distribution of selected papers across years

Figure 3 illustrates a consistent upward trend over the course of the 14-year period. The most significant surge happened from 2021 to 2022 when examining the citations. However, there

was a similar rise in publishing rates in both 2015 and 2018. A parallel pattern is evident in relation to the advancement of citations. L2 writing with technology-related publications earned a minimal number of citations in the first three years, especially between 2010 and 2012, when no citations were registered. The number of citations steadily increased from 2013 to 2023. The citation remained consistent between 2017 and 2018. By using advancements in productivity and citations, this particular field of study has consistently enhanced its h-index, increasing from around 0 in 2010 to 28 in 2023. The h-index had its most notable enhancement over the period from 2022 to 2023. Over time, studies have grown more based on theory and advanced in methodology, using rigorous methods and many sources of data, while also considering a wide range of contexts.

The analysis involved conducting an author keyword analysis to identify prevailing themes and trends in the field. Author keywords are instrumental in demonstrating the major research directions and trends in a given field (Kartal & Yeşilyurt, 2024). Using VOSviewer, the study analysed the cleaned data to uncover key research topics, trends, and patterns in technology enhanced L2 writing. The tool's capabilities in generating co-word maps and network diagrams were pivotal in visualizing the relationships between different concepts in the literature. This included creating a co-word map to depict connections between various keywords and concepts. Additionally, VOSviewer aided in identifying influential authors, institutions, and journals, and revealed collaboration patterns among them, thereby providing a comprehensive overview of the current state of research in L2 writing. In this article, the program utilized for the bibliometric study was CiteSpace (Chen, 2006). The CiteSpace program, which is a commonly utilized bibliometric analysis tool that scholars use to investigate the development trends in a certain topic, generated knowledge maps using nodes and connections as its primary components. The time interval was configured to be 1 year, and the term source encompassed the title, abstract, author, keywords, and supplemental keywords. The node categories, such as nation, institution, journal, author, keyword, and reference, were chosen based on the specific requirements of the research.

3. Findings and Discussion

This section supplies the findings categorized according to the research questions. The text contains a concise overview of important topics and patterns, showcases notable writers, preserves significant sources and references, and delineates prospective avenues for further investigation. Furthermore, it explores unresolved inquiries and difficulties in L2 writing, offering valuable perspectives on the present condition of the subject and promising avenues for future research.

3.1. Dominant Themes and Trends

An examination of the co-occurrence of author keywords indicates that the area is extremely diverse and encompasses a wide range of methods and methodologies. Furthermore, there are strong linkages among many of the issues within the field. Our analysis yielded L2 writing,

collaborative writing, AWE, CMC OR CALL. Figure 4 provides a graphic representation of the rising topics and trends in the field. L2 writing mainly concentrate on the CALL, collaborative writing and automated written feedback. The prevalence of terminology associated with Computer-Assisted Language Learning (CALL), Automated Writing Evaluation (AWE), and other digital platforms suggests a significant emphasis on using technology in second language (L2) writing teaching. This finding reflects the increasing integration of digital technologies into writing pedagogy and suggests that technology has evolved from a supplementary tool to a central component of L2 writing instruction.

Academic writing is also a widely discussed topic in the field of L2 writing. The prominence of academic writing may be attributed to the growing demand for academic literacy skills in higher education and the increasing use of technology-mediated writing support tools. Furthermore, the widespread use of AWE equipped with many different language learning apps has contributed to the L2 writing as a key trend (Wang et al., 2013). The map illustrates several links among clusters, suggesting that research on L2 writing is characterized by a diverse and linked nature. Terms associated with feedback systems, including both automated and peer feedback, are connected to collaborative learning and technology-assisted learning, demonstrating an interdisciplinary approach. Dominant trends in L2 writing research are indicated by keywords such as "flipped classroom," "Google Docs," "blog," and "online language learning." These keywords show a growing integration of digital tools and platforms.

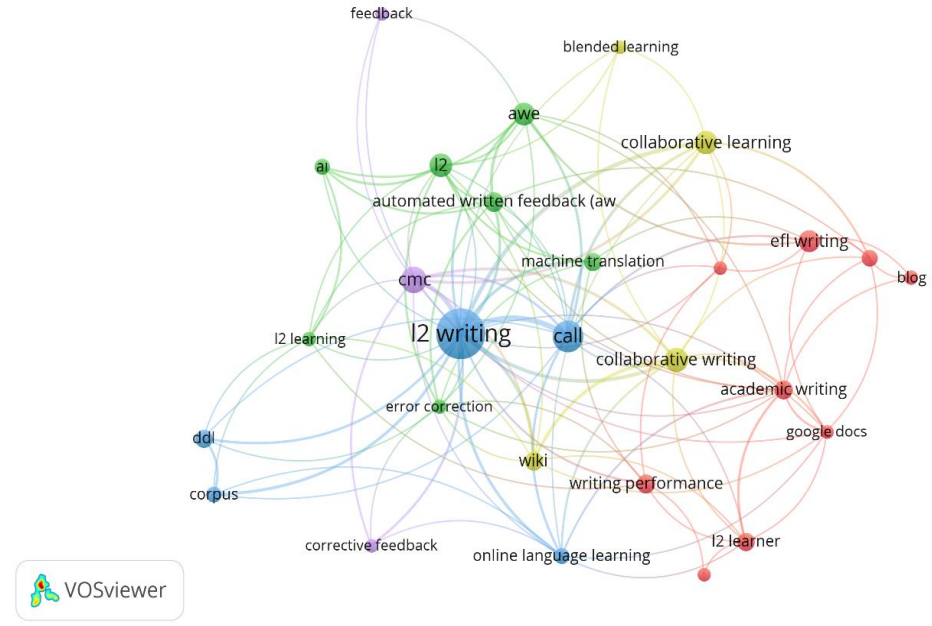

Figure 4. Analysis of dominant themes and trends: Co-occurrence of author keywords

In blue cluster, the major terms in the text are "L2 writing" with a total link strength of 79 and 69 occurrences, and "CALL" (Computer-Assisted Language Learning) with a total link strength of 35 and 27 occurrences (Chen et al., 2024). Additional significant terms include "corpus" with a total link strength of 10 and 7 occurrences, (Chen & Baker, 2010) and "DDL" (Data-Driven Learning) with a total link strength of 9 and 9 occurrences (Park, 2010; Wu, 2021). The prominence of CALL, corpus-based approaches, and DDL suggests that technology-enhanced L2 writing research has increasingly shifted toward evidence-based and learner-centered instructional practices.

The green cluster prominently features the key phrase "collaborative writing" with a total link strength of 26 occurrences. The strong presence of collaborative writing and peer feedback highlights the continuing influence of sociocultural perspectives, which view learning as a socially mediated process. This term signifies a noteworthy study topic that examines the effects of group writing on learning. "Collaborative learning, a term that encompasses a range of educational activities beyond writing, refers to the practice of students working together in a cooperative manner." (Total link strength = 22, occurrences = 15). "Peer feedback, which demonstrates a significant connection to collaborative writing, implies the need for research on peer-to-peer review mechanisms," (total link strength = 7, occurrences = 8). "Google Docs" (total link strength = 10, occurrences = 5) and "blog" (total link strength = 2, occurrences = 6). This cluster focuses on the development of collaborative and interactive learning environments and technologies specifically designed for second language (L2) writing. Google Docs and blog include the utilization of dedicated internet-based tools for cooperative writing and evaluation by peers as experienced by (Ebadi & Rahimi, 2017; Sun & Chang, 2012).

In the red cluster, terms are "L2 learning "(total link strength= 18 occurrences= 15) shows a broader focus on learning second languages, connected with automated tools (Liu & Yu, 2022; Yan, 2023). "AWE" (total link strength= 18 occurrences= 14) represents tools and systems that automatically assess and provide feedback on writing (Link et al., 2022). "Automated written feedback" (total link strength= 19 occurrences: 11) and "error correction" (total link strength= 12 occurrences= 6). This cluster appears to prioritize the utilization of automated technologies and the implementation of mistake correction techniques in second language writing as shown by (Barrot, 2023). The emergence of AWE and automated feedback as dominant themes reflects the growing interest in scalable feedback solutions and the increasing influence of AI-driven technologies on writing instruction.

The Purple Cluster is a smaller group that encompasses phrases such as "CMC" (Computer-Mediated Communication), (total link strength= 31 occurrences= 19) and "corrective feedback" (total link strength= 7 occurrences= 5). This cluster is most likely centred around online communication and learning tools. CMC focuses on the examination of online communication technologies in the context of second language (L2) acquisition and writing (AbuSeileek & Abualsha'r, 2014).

The Yellow Cluster shows terms like "learner autonomy," (total link strength= 5 occurrences= 5) focuses on how independent learning strategies affect L2 writing. "Writing performance" (total link strength= 8 occurrences= 10) evaluates the efficacy of various instructional techniques and resources on students' writing proficiency (Wang & Jiang, 2023). "L2 learner," (total link strength = 10 occurrences= 9) encompasses research on the traits and cognitive

processes of individuals acquiring a second language and "flipped classroom" (total link strength= 2 occurrences=5) proposes doing research on the pedagogical approach known as "flipped learning," which involves shifting the emphasis of writing assignments from the classroom to outside learning contexts (Chen Hsieh et al., 2017). This cluster appears to prioritize learner-centered techniques and performance measures in second language (L2) writing.

Further research indicates a notable concentration of interest in collaborative learning, specifically in exploring how collaborative approaches and technologies might improve L2 writing abilities. The inclusion of automated feedback and error correction as crucial concepts underscores the continuous investigation into the ways in which these technologies might facilitate the advancement of L2 writing skills. Considering the interrelatedness of the keywords, more investigation might be advantageous by employing interdisciplinary methodologies that integrate perspectives from technology, pedagogy, and linguistics. There is a requirement for more thorough assessments of the efficacy of different digital tools and platforms in enhancing L2 writing proficiency. Research might investigate the effects of various instructional strategies, including those that encourage learner autonomy, on L2 writing competency.

3.2. Co-citation Keywords Themes on Citespace

In this study, we utilized Citespace to do co-citation analysis of keywords. Upon selecting the "edit properties" option, we designated the duration as 14 years. The outcome we obtained was 257, which corresponded to the list we had noted. Nevertheless, upon selecting -1, we obtained a total of 547 outcomes, which proved to be unsatisfactory. It is crucial to emphasize that a maximum of 300 files can be approved. We chose all the choices available under the team source and specified the node type as Keyword. In the label area, we chose "K" as it represents the term "Keyword". Next, we opted for burstnesses and made our selection based on clusters. Time slicing with a G-index of 14. The map is presented in the following manner:

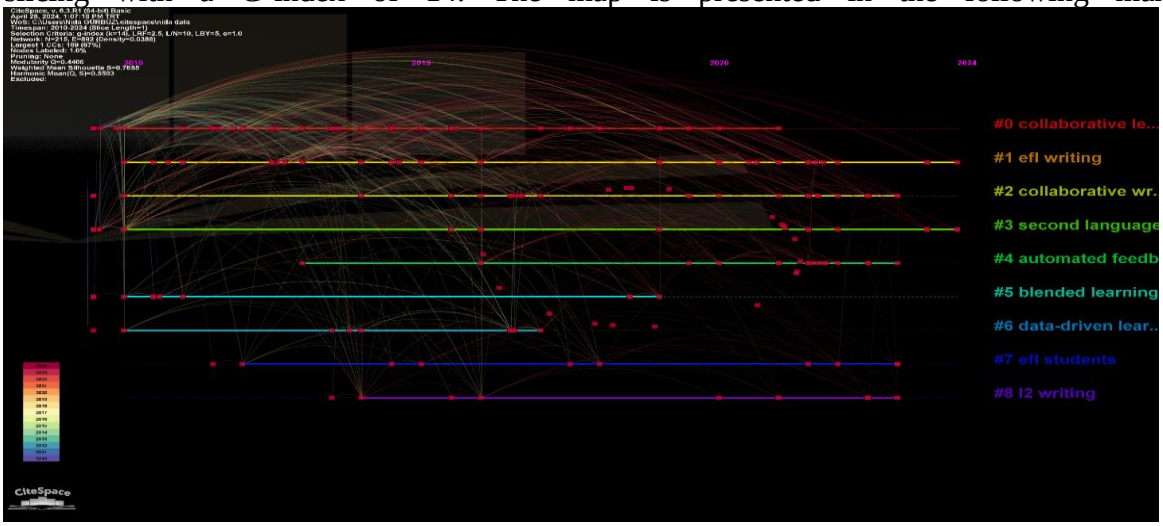

Figure 5. Timeline view of the co-citation network or keyword themes by burstness for the period 2010–2024 generated by CiteSpace.

This map represents a graphic chronology that shows the co-citation or theme patterns in the field of L2 writing study. The timeline on the X-axis spans from 2010 to 2024 until April, displaying the progression of research themes during this period.The Y-axis themes or clusters are organized by color and indicated on the right side. Every horizontal line indicates a distinct theme grouping. Clusters constitute the largest research area and the silhouette value is 0.765, suggesting high homogeneity among their respective cluster members. Every cluster is assigned a unique number and is identified by a specific study subject, which may be examined in depth:

#0 Collaborative Learning (Red) emphasizes the significance of collaborative learning in (L2) writing (Kessler & Bikowski, 2010; Hsieh, 2017). The timeline demonstrates a consistent and uninterrupted level of interest spanning from 2010 to 2024. Key Publications seek significant nodes, which are likely to be key publications on collaborative learning and interaction in L2 writing. The linkages demonstrate the continuous incorporation of recent research with fundamental studies, illustrating the enduring significance of collaborative learning as a central subject

#1 EFL Writing (Orange) focuses on the development of writing skills in English as a Foreign Language (EFL). It extends across the whole timeframe, demonstrating a continuous and ongoing study effort. Key Publications highlight important nodes that reflect notable publications on techniques, difficulties, and pedagogies related to English as a Foreign Language (EFL) writing. The consistent connections imply a firmly established domain with ongoing contributions that build upon previous studies.

#2 Collaborative Writing (Yellow) focuses on the procedure of jointly creating written works. The cluster exhibits significant activity and expansion. Significant research may encompass technology-facilitated collaborative writing and peer feedback techniques. (Bikowski & Vithanage, 2016). Recent evidence suggests that emerging trends are expected to entail the use of digital platforms to facilitate collaborative writing.

#3 Second Language Acquisition (green) encompasses a wide range of topics related to the learning of a second language, which has a direct influence on studies in L2 writing. The focus here is on influential publications that explore theories of Second Language Acquisition (SLA) and their practical application to writing. The connections between links and nodes demonstrate the ongoing impact of SLA research on writing education and technique.

#4 Automated Feedback (Ranalli, 2018) is the focus on systems and their significance in L2 writing. The emergence of automated feedback as a distinct cluster indicates a shift from traditional feedback approaches toward technology-mediated writing support systems, particularly in response to advances in artificial intelligence and natural language processing.

#5 Blended Learning (Blue) (Lam et al., 2018) integrates conventional and digital approaches in L2 writing education. Key Publications seek influential research on blended learning strategies and their effectiveness. The distribution of nodes and linkages throughout time demonstrates the way in which blended learning has adjusted and developed in response to technological progress.

#6 Data-Driven Learning (Purple) utilizes corpora and data-driven methods to guide the teaching practices of second language (L2) writing. Important focal points may include studying the utilization of corpus linguistics in teaching writing. The emergence of connections indicates

a rising dependence on empirical data to improve instructional approaches. This trend suggests an increasing reliance on empirical language data to support writing instruction and learner autonomy.

#7 EFL Students (Pink) is the main emphasis on English as a Foreign Language (EFL) students, their distinct difficulties, and successful teaching methods. (Chen, 2016). The focus here is on studies that examine student-centered methods and tailored learning methodologies. Continued interest in customizing writing training to suit the requirements of EFL students is indicated by persistent linkages and nodes.

#8 L2 Writing (Deep Blue) includes a wide range of teaching approaches, difficulties, and results. This cluster encompasses fundamental and extensive research on L2 writing.The comprehensive chronological coverage demonstrates the increased variety and expansion of L2 writing studies across the years.

The subject of discussion pertains to trends and emerging areas. The multitude of connections within clusters indicates a significant level of interdisciplinary collaboration. For instance, the correlation between automated feedback (#4) and collaborative writing (#2) emphasizes the incorporation of technology in collaborative learning settings (Yamashita, 2021). In recent years, there has been a noticeable increase in the number of nodes and connections related to automated feedback (#4) and blended learning (#5). This indicates a growing research interest and breakthroughs in these fields. Themes such as English as a Foreign Language (EFL) writing (#1) and Second Language (L2) writing (#8) have a steady level of research activity, indicating established and continuous study interests.

In future research, researchers can promote the integration of elements from various clusters. For example, they can incorporate automated feedback systems into collaborative writing environments. Additionally, they can further explore the use of data-driven learning approaches to gain evidence-based insights into effective second language (L2) writing instruction. Furthermore, researchers should continue to investigate the specific needs of English as a Foreign Language (EFL) students and develop customized instructional strategies to address their particular challenges. This timeline visualization offers a thorough summary of the theme progression in L2 writing studies. Through the examination of significant clusters, their linkages, and developing patterns, we get vital understanding of the historical, current, and future trajectories of the discipline. This approach can provide researchers with valuable guidance in identifying promising topics for further exploration and promoting multidisciplinary cooperation.

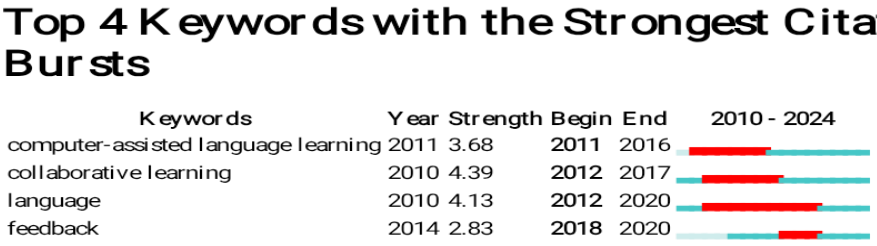

Figure 6. Top 4 keywords with strongest citation bursts in L2 writing.

The significant increase in citations for "computer-assisted language learning" (CALL) between 2011 and 2016 indicates a concentrated time of scholarly attention towards the incorporation of technology in language teaching. During this period, researchers and educators were probably investigating the effectiveness, methodology, and instruments used in Computer-Assisted Language Learning (CALL). A burst strength of 3.68 suggests a significant and notable increase in citation activity (Fidaoui et al., 2010). This burst likely reflects the rapid expansion of digital learning environments and growing interest in technology integration during the early development of technology-enhanced language learning.

The term "collaborative learning" underwent a substantial increase in citations from 2012 to 2017, with a strength value of 4.39, suggesting noteworthy scholarly attention. Collaborative learning entails the collective effort of students to resolve issues, accomplish tasks, or comprehend novel ideas.

The term "language" saw a significant increase in citations from 2012 to 2020, reaching a strength of 4.13. This extended period of intense activity indicates a consistent and enduring fascination in different facets of language studies over almost ten years.

The term "feedback" had a significant increase in citations from 2018 to 2020, with a strength of 2.83. The increasing prominence of feedback may indicate a growing recognition of feedback as a critical factor in supporting writing development and learner engagement. This suggests a rising scholarly interest in examining the role and influence of feedback in educational and other settings.

The citation bursts associated with these terms indicate the changing patterns and core areas of focus in academic research and practice throughout the years. The use of technology in language learning, the focus on collaborative methods, the widespread interest in language studies, and the crucial function of feedback all indicate important areas of advancement and creativity in the domains of education and linguistics.

3.3 Citation analysis of documents

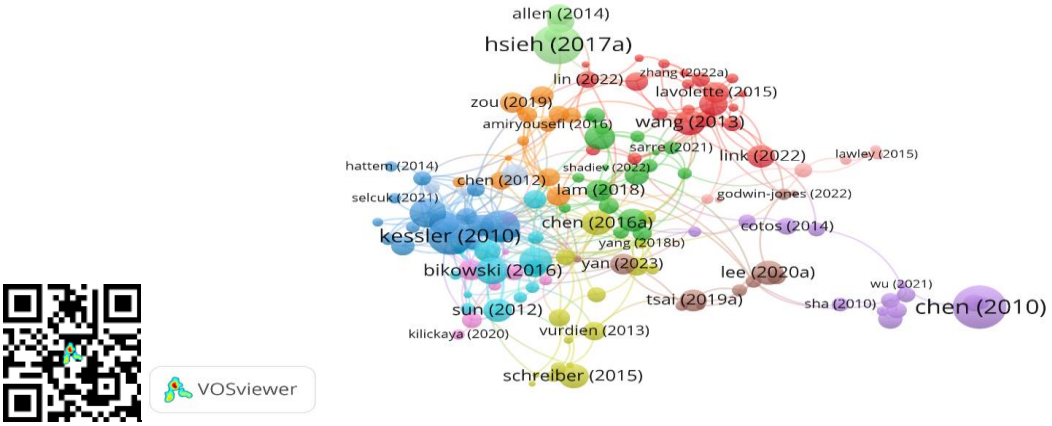

Figure 7. Visualization of documents

We set the threshold to 5. There are a total of 146 elements, and they are divided into 12 clusters. The core node in the blue cluster is Kessler and Bikowski (2010), with a link value of 25 and a citation value of 183. This article is probably a groundbreaking achievement in its field, as evidenced by its prominent position and significant node size. Another significant contributor is Li and Zhu (2013) (link=18 Citation: 116), who appears to have expanded upon or has a strong connection to Kessler's work. Awada et al. (2020) represent more recent work that has also gained recognition in this cluster. The strong links imply that this cluster may be centered around a firmly established research field, such as technology in education, specifically in relation to language acquisition or instructional design. Bikowski and Vithanage (2016) (link= 17 Citation=96) is a prominent publication that has tight interactions with other publications in the cluster. Zhang et al. (2023) (link = 13, citations = 30) represent emerging research directions or recent advancements in the field.

Green Cluster comprises of Chen Hsieh et al. (2017) (link = 5, citations = 216) represent a foundational work within this cluster, suggesting significant contributions to educational technology and e-learning. Representing newer research trends, this publication might focus on innovative aspects of L2 writing, such as the use of technology or new theoretical frameworks that address contemporary challenges in language education. Hwang et al. (2014) are shown as a central node (link = 7, citations = 86). Key Themes mostly centers around cutting-edge educational techniques, e-learning approaches, or learning settings that are improved by technology (Hwang et al., 2014).

In red cluster central nodes are Ranalli (2018) (link=15 citation= 74) a prominent publication demonstrating substantial influence in the subject, maybe pertaining to language learning or educational evaluation. Wang et al. (2013) (link= 10 citation= 90), Link et al. (2022) (link=7 citation=69). The red cluster has a high degree of interconnections, indicating the presence of a tightly knit subfield. The main focal points are language acquisition, evaluation methods, and cognitive strategies in education.

Purple Cluster appears to be centered around a highly influential work or author and includes Chen and Baker (2010) (link= 1 citation= 251) as a central node. This article is a crucial and influential work in this particular group, indicating that it has established an important standard in its field of research (Chen & Baker, 2010). Key Themes may center on a specialized domain within the wider subject, such as unique approaches in educational technology or certain theoretical frameworks. Positioned at one end of the network with numerous connections stretching across the entire map, this author acts as a significant node, indicating heavy citation by other researchers and likely a broad portfolio of influential publications. Often cited as an inspiring work, this publication likely provides fundamental insights or a pivotal methodology that has shaped subsequent research in L2 writing.

Yoon (2016) (link=5 citation=32) and Wu (2021) (link=5 citation=9) are related works that build upon the central theme but are more specialized. Nodes like "Cotos (2014)" (link=2 citation=39) (Cotos, 2014) and "Sha (2010)"(link=2 citation= 26) have a more peripheral nature, indicating that they may be either recent works that have not yet garnered a significant number of citations or specialist works within the area (Sha, 2010).

This bibliometric network offers a thorough and all-encompassing representation of the research environment within specific discipline. Through the examination of the central nodes and clusters, one may ascertain significant publications, notable authors, and developing trends. This analysis can provide valuable guidance for literature study, assisting within the current research landscape and identifying prospective partners or areas where the literature is lacking. Key publications from authors such as Kessler and Bikowski (2010), Chen and Baker (2010), and Chen Hsieh et al. (2017) play a crucial role in the network, suggesting that they are fundamental or extremely important in the area.

3.4. Co-citation of Cited Sources

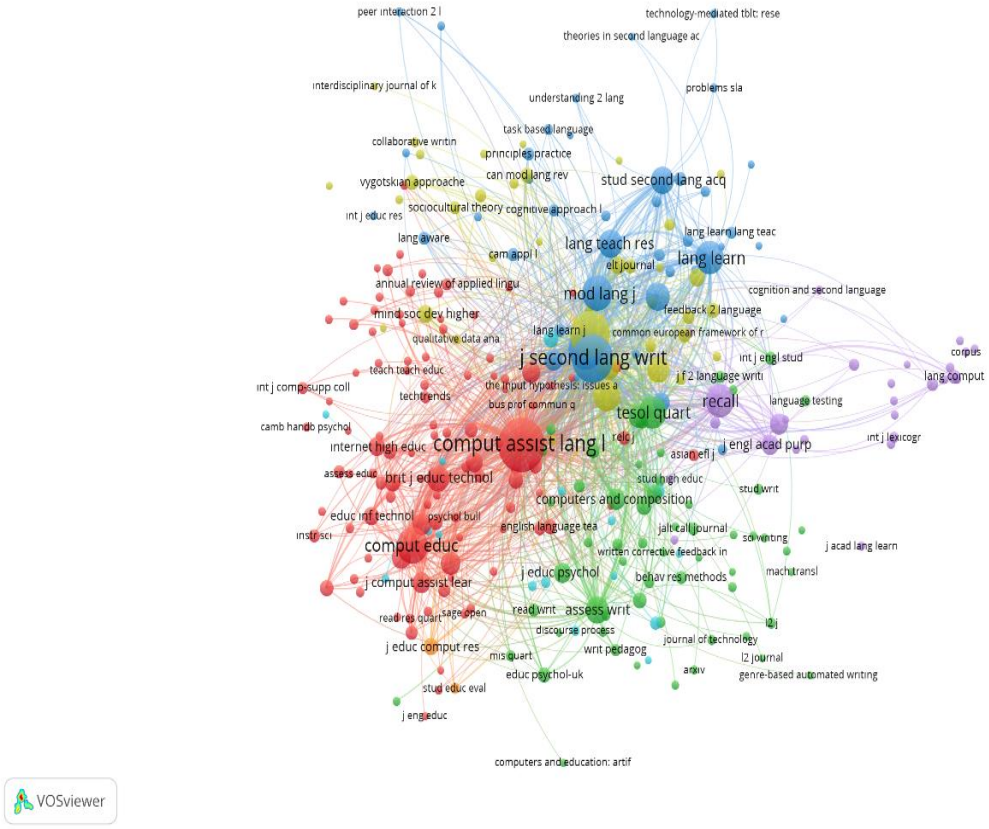

Figure 8. Co-citation Analysis Cited Sources

Red Cluster comprised of "comput assist lang" (Computer-Assisted Language Learning), the central aspect of this cluster signifies a pronounced emphasis on using technology into language learning procedures, (total link strength= 26085 citation= 706) "comput educ" (Computer

Education), highlighting the significance of computers in education in a comprehensive manner, extends beyond the scope of language acquisition (total link strength= 8920 citation= 236). “Brit j educ technol" (British Journal of Educational Technology), a distinguished publication that regularly publishes relevant research in this field (total link strength= 3996 citation=106). This cluster centers on the integration of computer technology in language learning and education. The study centers on the instruments, tactics, and impacts of computer-assisted learning. This cluster focuses on exploring a range of digital tools and platforms that are utilized to enhance language learning. This includes software programs, online resources, educational games, and strategies for effectively incorporating technology into language teaching approaches.

Green cluster included “TESOLQuart (total link strength=6452 citation= 173), computers and composition, which refer to the study of the impact of computers on the process of writing and composition (total link strength= 2401 citation= 60). Central keywords are “assess writ”, “writ pedagog”, “j educ psychol” and “writ commun”.

Blue cluster is centered on the pedagogical methods used in language instruction as well as the learning of second languages. Central Keywords in blue cluster are “j second lang writ” (Journal of Second Language Writing) (total link strength= 20009 citation= 526), "mod lang j" (Modern Language Journal) (total link strength= 8472 citation= 219), lang learn" (Language Learning) (total link strength= 7921 citation= 197), "lang teach res" (Language Teaching Research) (total link strength= 5172 citation= 118).

Additional noteworthy terms include "lang aware" (Language Awareness), which refers to an understanding of language and its use, and "task-based language," which focuses on particular methods for learning and teaching languages.

Yellow cluster is consisted of central nodes, “lang learn technol” (Language learn technology), (total link strength= 15384 citation= 454), “calico” total strength= 6306 citation= 168). Central keywords are blog, wiki, podcasts, call and vygotskian approaches.

Purple Cluster’s central keywords are lang comput" (Language and Computers), (total link strength= 521 citation= 19) “lang corpus" (Language Corpora), (total link strength= 165 citation= 7). This cluster focuses on the utilization of computer technologies and corpus linguistics in language study. Key Themes are corpus linguistics, computational linguistics and"int j lexicogr" (International Journal of Lexicography), (total link strength= 320 citation= 10), suggesting a concentration on the study of words and their meanings, as well as the use of computer analysis to understand language.

The terms "comput assist lang", "stud second lang acq", and "j second lang writ" indicate the main topics in the discipline, which encompass the use of technology in language learning, the process of acquiring a second language, and academic writing in a second language.

The visualization demonstrates substantial convergence and interconnections within clusters, suggesting a high level of interdisciplinary nature in study areas. Studies on second language learning have a strong connection with educational technology and writing. Based on the cluster analysis results, the "British Journal of Educational Technology", "Journal of Second Language Writing", and "Modern Language Journal" have been identified as prominent sources in the topic.

3.5. Co-citation Analysis of Cited References

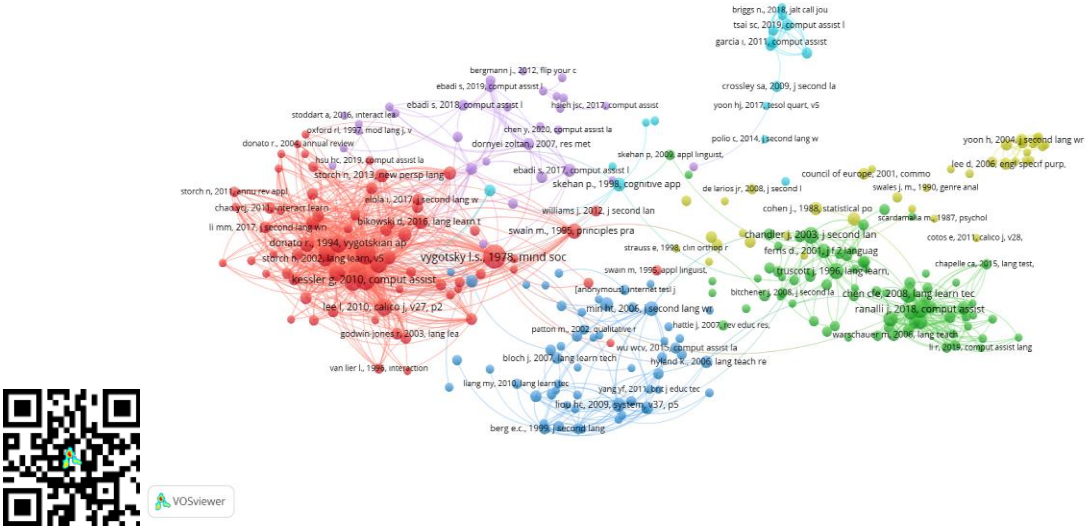

Figure 9. Co-citation Analysis of Cited References

The Red Cluster is characterized by a high population density and a strong emphasis on fundamental ideas and important works in the field of language acquisition and instruction. Notable authors in this field include Vygotsky (1978), (total link strength= 514 citation=40) Storch (2013), (total link strength= 244 citation=13) and Donato, (1994), (total link strength=146 citation=5) examines language learning from a socio-cultural perspective. Esteemed scholars such as Vygotsky (1978) Known for "Mind in Society", Vygotsky's research on the socio-cultural theory of cognitive development is essential for comprehending the process of language acquisition (Donato, 1994; Storch, 2013) is renowned for her contributions to the field of collaborative writing and interaction in second language acquisition. These publications have received significant attention and are considered fundamental in the area. This cluster is most likely a representation of the fundamental theoretical frameworks and prominent research in the field of second language learning.

Green Cluster may be prioritizing computer-assisted language learning (CALL) and the incorporation of technology in language education. Notable authors in this field are Chandler (2003) (total link strength= 282 citation= 19) conducted research on mistake correction and feedback in Computer-Assisted Language Learning (CALL). Truscott (1996) (total link strength= 284 citation=17) renowned for his critical perspectives on mistake correction in language learning, and Warschauer (2006) total link strength=189 citation=19) is a renowned figure in the field of Computer-Assisted Language Learning (CALL) and has made significant contributions to the integration of digital technology in language instruction.

The blue cluster likely represents contemporary studies and practical research, maybe emphasizing language evaluation and teaching methods. Some noteworthy works include those by Liou (total link strength= 257 citation= 13) and Min (total link strength=204 citation=14).

The yellow cluster's central authors are Yoon and Hirvela (2004) (total link strength= 68 citation=10), examines the specific area of second language writing and feedback and Lee D (total link strength= 90 citation=9).

The purple cluster might be focused on certain techniques or specialized areas within language learning, such as flipped classrooms or unique pedagogical approaches. A notable work in this cluster is Ebadi and Rahimi (2019) (total link strength = 142, citations = 7), which examined online dynamic assessment using Google Docs.

3.6. Citation Analysis of Influential Authors

Figure 11. Key Authors with Strong Citation Bursts on Citespace

This table offers a thorough synopsis of the most prominent writers within the past decade, highlighting their contributions and the changing patterns in language education research. Authors who see significant increases in citations are often linked to research in computer-

assisted language learning (CALL), online resources, and the integration of technology in language education. This suggests a clear inclination towards the use of digital learning technologies.

Johns (1991) is renowned for his contributions to the field of corpus linguistics and data-driven learning between 2010 and 2017. The burst strength of this phenomenon is measured at 3.68. He has a significant influence on the area of language acquisition through the use of corpora over the period from the early 2010s to mid-2017. Blake (1987) has expertise in the field of computer-assisted language learning (CALL) between 2010 and 2015. The burst strength is 3.09 units. The impact phase occurred in the early 2010s and was remarkable for his contributions to the integration of technology in language teaching. Pinkman (2005) is well-known for their research conducted between 2010 and 2015 on online collaborative writing. The burst strength is 3.09 units. The Impact Period refers to the early 2010s and is significant in terms of digital literacy and collaborative learning. Lee's citation burst ran from 2013 to 2018 and concerned language learning. The burst strength is 5.24. The Impact Period occurred in the mid-2010s and had a substantial influence on the utilization of technology in language classes. Leki (2006) focuses on writing and feedback as they relate to learning a second language between 2013 and 2017. The burst strength is 4.24 units. The impact era occurred in the mid-2010s and was crucial for gaining valuable knowledge about successful methods of teaching writing and providing feedback.

Chambers and Bax's (2006) works implemented computer-assisted language learning (CALL) and digital technologies for language acquisition in 2014 and 2017. The burst strength is 3.73 units. The impact phase occurred in the mid-2010s and played a significant role in enhancing our comprehension of digital tools in language instruction. In the works of Boulton and Tyne (2013), they conducted research on the use of corpus utilisation and data-driven learning in education from 2014 to 2017. The burst strength is 3.31 units. The impact phase occurred in the mid-2010s, leading to an increased use of corpora in language instruction. Liu specializes in the study of second language writing in the years between 2014 and 2016. The burst strength is 3.04 units. The impact era of this phenomenon occurred throughout the mid-2010s.

Warschauer's citation burst occurred in 2015-2016 and concerned technology and digital literacies in education. The burst strength is 5.07 units. The impact phase occurred in the mid-2010s and had a significant influence on the development of digital education initiatives. Liou did research on computer-assisted language learning (CALL) and educational technologies between 2015 and 2016 time period. The burst strength is 3.95 units. The impact era occurred throughout the mid-2010. From 2015 to 2017, Lee's citation burst concerned online language learning platforms and e-learning. The burst strength is 3.77 units. The impact phase occurred throughout the mid-2010s and had a significant influence on the advancement of online educational technologies. Kern (2015) looks into how language and literacy skills are picked up between 2015 and 2017. The burst strength is 3.77 units. The impact period of his study occurred in the mid-2010s, focusing on the convergence of language acquisition and literacy development. Research on computer-assisted language learning (CALL) with an emphasis on Arab-speaking contexts is carried out by AbuSeileek and Abualsha'r (2014) between 2016 and 2018. The Burst Strength is 3.26 units. The impact phase occurred in the late 2010s, which improved the comprehension of Computer-Assisted Language Learning (CALL) in many

cultural contexts. In the years 2017–2018, Cumming (1990) focuses on the topic of second language writing and evaluation. The burst strength is 3.32 units. The impact period, which occurred in the late 2010s, had a significant influence on the development of research and evaluation procedures in the field of writing.

Chandler (2003) primarily emphasizes the need of providing feedback and using error correction techniques in the context of writing in 2018-2021 time period. The burst strength is 3.19 units. The effect period occurred from the late 2010s to the early 2020s, affecting the tactics used for providing feedback in language instruction. Pica (2013) focused mostly on the investigation of SLA and interaction within the years 2018–2021. The burst strength is 3.07 units. The impact phase occurred from the late 2010s to the early 2020s and was particularly significant for interactionist techniques in SLA.

Bitchener (2017) focuses on written corrective criticism during the 2019–2021 timeframe. The burst strength is 3.48 units. The impact phase is expected to occur in the early 2020s, influencing the methods used to deliver appropriate written feedback. Creswell and Poth (2018) investigate several research approaches in 2019-2022 time period. The burst strength is 3.32 units. The Impact Period is expected to occur in the early 2020s, which will have a significant influence on the study designs used in educational studies. Truscott examines the process of correcting grammar in second language acquisition (SLA) in the years of 2021 and 2024. The burst strength is 3.25 units. The impact period is expected to occur from the early 2020s to the mid-2020s, and it is characterized by the prevalence of critical perspectives on grammar correction. Ranalli (2018) are doing a study on the intersection of learning technology and language. The burst strength is 5.04 units. The impact period is now making substantial contributions to Computer-Assisted Language Learning (CALL) and learning technologies.

Rahimi and Fathi's (2022) study investigates how technology might support language learning throughout the 2022–2024-time frame. The burst strength is 4.2 units. The impact phase is now prominent in the integration of technology in language teaching. Rahimi explores the use of technology to aid the process of learning a language. The burst strength is 4.2 units. The impact phase is now prominent in the integration of technology in language teaching. Zhang et al.'s (2020) research from 2022 to 2024 is centered around the study of e-learning and blended learning. The burst strength is 3.35 units. The impact phase is currently occurring, which is contributing to the use of hybrid learning models. Lee (2022) investigates the field of online language learning in the years between 2022 and 2024. The burst strength is 3.07 units. The Impact Period is now affecting online and remote learning practices. Li investigates the process of acquiring a second language and its relationship with technology in the years of 2022- and 2024. The burst strength is 3.07 units. The impact period is now ongoing and is well-known for its focus on the role of technology in second language acquisition (SLA). In 2022 and 2024, Strobl will be pursuing research in the area of computational linguistics. The burst strength is 3.07. The impact period is ongoing, and it is making a valuable contribution to the field of computational techniques in language acquisition (Strobl et al., 2022). Between 2022 and 2024, prominent authors such Ranalli and Rahimi have appeared, making substantial advancements in the realm of educational technology and its use in language teaching.

3.7. Co-authorship of Countries

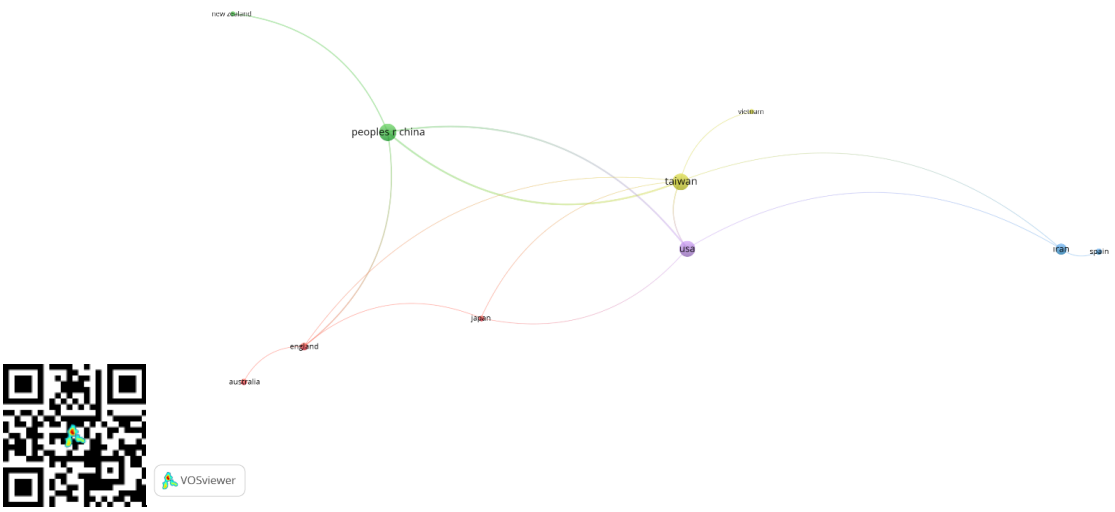

Figure 12. Co-Authorship Analysis of Countries

We set a threshold of 5. The item has a value of 10. The cluster has a value of 5. The network visually represents the connections among various nations, which are determined by their collaboration in producing scholarly articles. The network appears to exhibit the formation of clusters across nations, which can be attributed to geographical factors as well as potential language or regional connections. Below is a comprehensive examination of the network:

The central node represents the People's Republic of China, with a total connection strength of 17 and a document count of 52. This node is quite big, suggesting that it contains a substantial number of co-authorship links. The size of this node is indicative of China's significant contribution to global research output. China's global network extends across several nations, demonstrating its significant international partnerships. It establishes connections with other nations, including New Zealand, Taiwan, the USA, and England.

The USA serves as a significant node, connecting with Taiwan, Iran, Japan, and Spain, demonstrating a substantial amount of international cooperation. The peripheral nodes, including New Zealand, Vietnam, Iran, and Spain, have less co-authorship relationships in comparison to the centre nodes.

The length of the lines (edges) connecting the nodes represents the strength or frequency of collaboration between those countries. Increased line thickness corresponds to greater strength or frequency of cooperation. For instance, the relationship between the United States and Taiwan is robust, indicating a significant occurrence of collaborative publications. The links between the People's Republic of China and other nations are abundant and relatively dense, suggesting a vast yet diverse range of collaborations. Asia exhibits a prominent representation of nations such as China, Taiwan, Vietnam, and Japan, indicating the existence of robust research networks within the area. European and Oceanic countries, such as England, Australia,

New Zealand, and Spain, also demonstrate substantial collaboration, but in a more scattered manner.

In conclusion, this co-authorship network map offers significant insights into the worldwide research cooperation scene. Through the identification of influential individuals and the analysis of patterns of collaboration, stakeholders may make well-informed decisions to improve international research endeavors, foster inclusivity, and tackle global concerns by means of scientific cooperation.

4. Conclusion

This study provides a comprehensive bibliometric overview of technology-enhanced L2 writing research published between 2010 and April 2024. By examining publication trends, influential authors, institutions, countries, sources, and research themes, the study reveals the intellectual structure and developmental trajectory of the field. The findings demonstrate that research on technology-enhanced L2 writing has expanded considerably over the past decade, reflecting the increasing integration of digital technologies, collaborative platforms, and artificial intelligence-based tools into language learning and instruction.

The study also highlights the dynamic nature of the field by identifying shifts in research interests and thematic priorities over time. Emerging topics such as collaborative writing, automated feedback, and technology-mediated language learning have gained increasing prominence, indicating the evolving needs and directions of L2 writing research. These findings provide valuable insights into the major knowledge domains, influential contributors, and research trends that have shaped the field. Unlike previous review and bibliometric studies that focused on specific journals, limited datasets, particular technologies, or empirical studies alone, the present study offers a broader perspective by analysing publications indexed in the Web of Science database across a fourteen-year period. Furthermore, the inclusion of different article types, the implementation of a systematic data-cleaning procedure, and the combined use of VOSviewer and CiteSpace enabled a more comprehensive examination of the field's intellectual and thematic development. In this regard, the study contributes a detailed and up-to-date mapping of technology-enhanced L2 writing research.

Despite these contributions, several limitations should be acknowledged. The analysis was restricted to the Web of Science Core Collection and included only English-language publications. Consequently, relevant studies indexed in other databases or published in other languages may not have been captured. Future research could broaden the scope by incorporating additional databases, multilingual publications, and complementary qualitative analyses to provide a more comprehensive understanding of the field. Overall, this study offers a valuable reference point for both established and emerging researchers by identifying influential research themes, publication trends, and future directions in technology-enhanced L2 writing. The findings contribute to a deeper understanding of the field's evolution and may assist researchers, language educators, and curriculum developers in making informed decisions regarding the integration of emerging technologies into L2 writing instruction.

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Declaration of Conflicting Interests and Ethics

The author declares no conflict of interest. This study did not involve human participants or animal subjects. Therefore, ethical approval was not required.

AI Use Statement

The authors confirm that AI tools were not used at any stage of the study in order to formulation of the study content, conducting data analysis, generating research findings, or for any critiques central to this research.

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