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Evolution and Trends in EFL/ESL Vocabulary Development in Higher Education: Bibliometric and Content Analysis (1984–2024)

ThiTuyet Tran¹ , Apisak Sukying² , Pilanut Phusawisot^{2*} 

¹ Faculty of English Language Studies, Hanoi University of Business and Technology, Hanoi 100000, Vietnam

² Department of Western Languages and Linguistics, Mahasarakham University, Maha Sarakham 44150, Thailand

ABSTRACT

The current study presents a systematic bibliometric review on English as a Foreign Language (EFL) and English as a Second Language (ESL) vocabulary research in higher education from 1984 to 2024. Using 601 Scopus-indexed articles as a dataset, the research analyses trends in publications, research collaboration networks, leading authors, prominent journals, main thematic directions and emerging research gaps. By employing descriptive statistics, co-word analysis, and bibliographic coupling, the study systematically maps the intellectual and structural landscape of the field. The findings indicate a gradual increase in publication trends over the last two decades, with Iran, China, and the United States being the most productive and significant contributors to co-authorship. Key research topics include receptive versus productive vocabulary knowledge, incidental vocabulary learning, mobile-assisted language learning, and data-driven learning. Although there is an increasing interest in technology-assisted vocabulary learning, the study indicates a lack of research into the sustainability, scalability, and contextual adaptability of such innovations. The findings underscore the importance of interdisciplinary work, culturally responsive pedagogy, and longitudinal empirical research to inform future studies. Combining a historical overview, discussion of key authors, and directions in the field, it provides rich material to advance knowledge on and teaching of vocabulary development from an EFL/ESL perspective at the university level.

Keywords: Vocabulary Development; Higher Education; Bibliometric Analysis; Content Analysis; Research Trends

*CORRESPONDING AUTHOR:

Pilanut Phusawisot, Department of Western Languages and Linguistics, Mahasarakham University, Maha Sarakham 44150, Thailand;
Email: pilanut.p@msu.ac.th

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1. Introduction

Teaching and learning vocabulary are essential for understanding and learning a language, especially in EFL and ESL contexts. It is accepted as a multifaceted dosage for developing reading, writing, listening, and speaking skills^[1,2]. The centrality of vocabulary in language acquisition^[3] is also emphasized by^[4] in his paper. Significant advancements have occurred in vocabulary teaching over the last four decades. Early work, conducted in the late 1980s and throughout the 1990s, aimed to differentiate between receptive and active vocabulary and evaluate the span of vocabulary knowledge^[1,5]. Current studies have attempted to incorporate technology-integrated learning, utilizing multimedia and adaptive technologies to support students in learning vocabulary^[6].

However, there are still research gaps that must be addressed. One such void is in the identification of various instructional strategies for vocabulary acquisition and the practical implications of some of these approaches for learning in diverse educational settings^[7]. More crucially, there is a need to assess the sustainability and effectiveness of these learning approaches in the long run^[8]. Another void relates to the applicability of adaptive learning technologies, which have not been adequately researched in terms of diversification among learners and environments^[9]. Additionally, research is scarce on the collaboration of cognitive science, educational technology, and linguistics to develop a more integrated approach to improving vocabulary^[10]. This literature also raises awareness of the need for more studies that examine specific approaches to developing learners' vocabulary in higher education and other non-conventional learning institutions^[11].

To address this gap in the literature, the current research seeks to provide a systematic review of studies on L2 vocabulary in higher education EFL/ESL (1984–2024). In particular, the research maps the historical evolution of vocabulary research in this area, traces major themes present, and identifies top contributors and source journals that have influenced academic dialogue. In tracing the intellectual topography of the domain, this review presents an opportunity to understand the development and current trends in EFL/ESL research on vocabulary development while pinpointing salient research themes and informative sources of knowledge. It also suggests some directions for future

research, including the implementation of a large-scale, sustainable vocabulary acquisition method and consideration for various theoretical frameworks. Given these considerations, this paper attempts to address the following research questions:

1. What are the publication trends and key contributors in EFL/ESL vocabulary development research from 1984 to 2024?
2. Which journals, information sources, and thematic areas have most significantly influenced EFL/ESL vocabulary development research?
3. What are the emerging research themes and potential directions for future research in vocabulary development in higher education EFL/ESL contexts?

2. Literature Review

This section presents a review of recent systematic literature reviews to identify critical research gaps and provide rationale for a large-scale study of EFL/ESL vocabulary trends in higher education settings over the last four decades. In other words, previous reviews have been limited in significant ways, due to methodological flaws, regional and demographic biases, and insufficient consideration of theoretical and technological innovations. These constraints reflect the requirement for a more holistic and comprehensive integration of related research.

One review helps provide the insight for the role of social media platforms (SMPs) in vocabulary acquisition^[7], particularly in Saudi Arabia and Southeast Asia, from 2014 to 2018. The results highlight the beneficial effects of the SMPs on learner motivation and vocabulary learning. However, the narrow geographical and temporal proximity precludes generalization in larger global contexts, especially in higher education. This raises the call for longitudinal and cross-regional investigations that focus on integrating SMPs with vocabulary instruction within undergraduate teaching.

Another review provides a detailed survey of technology-aided vocabulary learning^[9], with the target audience being mainly learners in pre-kindergarten through 12th-grade education. Even if the review refers to theoretical perspectives related to both the educational use of CALL (Computer-Assisted Language Learning) and MALL (Mobile-Assisted Language Learning), as well as the educa-

tional context, no reference to the higher education system could be found. Additionally, the review does not include citation metrics to assess impact or publishing patterns. These gaps highlight the need for a bibliometric content analysis procedure that focuses on vocabulary research in higher education.

A systematic review of vocabulary assessment methods has also been conducted, although it has been limited to young language learners^[8]. The review provides informative details about the instruments and techniques used to measure children's vocabulary; however, its relevance to vocabulary instruction at the university level is below average. The lack of studies on vocabulary testing in adult academic environments is an important area for exploration.

Bibliometric research in mobile-assisted vocabulary learning (MAVL) has also been conducted, revealing countries with high research production and the principal authors^[4]. The review, on the other hand, also overlooks content analysis to compare changing research themes, broader instructional formats, or other possibilities for incorporating digital strategies in different ways or directions than the MAVL framework. As a result, a more comprehensive analytical framework is needed, one that encompasses a range of technologies and pedagogical developments in vocabulary teaching.

Furthermore, research on explicit vocabulary instruction in Asian ESL/EFL settings has made significant contributions^[11], but these appear to be local and education-specific. Focusing solely on Asian EFL students over 15 years, the review has little to say about teaching college students. Limiting the regional focus and excluding higher education viewpoints serve to underscore the necessity for a globally-representative and higher education-tailored synthesis.

In other words, despite the progress made by recent reviews, they are severely compromised in terms of scope, methodology, population studied, and analytical quality. More importantly, there are also no integrative studies that center on higher education, utilize bibliometric and content analysis, and encompass a range of instructional technologies and theoretical paradigms. To fill these gaps in the literature, the current study presents an integrative review of EFL/ESL vocabulary learning from 1984 to 2024. Our focus is on analyzing trends in publications, identifying major authors

and themes, and providing guidance for the development of inclusive and sustainable teaching practices in higher education.

3. Research Methods

This study's methodology combines bibliometric and content analyses to address its comprehensive research questions. This dual-method approach thoroughly examines the students' vocabulary development, aligning with the study's complex nature.

3.1. Bibliometric Analysis

Bibliometric analysis is the cornerstone of this research. Bibliometric analysis benefits from integrating techniques derived from citation analysis, computational sciences, and information visualization, thereby enhancing both analytical depth and breadth^[12]. Furthermore, the strengths of this method lie in synthesizing and scrutinizing extensive datasets to uncover latent patterns and emerging trends within the scholarly landscape^[13]. This study employed contemporary bibliometric practices utilizing tools such as Microsoft Excel and VOSviewer, which played a crucial role in the analysis. These tools facilitated a granular examination of publication trends, authorship networks, and thematic developments pertinent to English language learners' vocabulary development. Techniques such as co-word analysis and hybrid methodologies that combine bibliographic coupling with word analysis were employed to examine the structure and thematic development of the research field^[14]. Furthermore, the analysis of cited authors enhances this study's investigative capacity^[15]. The deployment of these sophisticated methodological approaches extended the scope of this research, positioning it at the forefront of academic inquiry and providing a comprehensive understanding of the dynamic interplays and thematic evolutions within the field.

3.2. Content Analysis

Content analysis complements the bibliometric analysis by providing a qualitative interpretation of the selected articles, aligning with this study's goal of offering a holistic view of EFL/ESL vocabulary development research. Following, content analysis involves coding and identifying

significant themes or patterns within the data, which is crucial for understanding the nuances and underlying trends in this field^[16]. This inductive coding approach involved familiarization with the data, generation of initial codes, identification of emerging themes, refinement of these themes, finalization and labelling of themes, and synthesis and reporting. This inductive thematic coding approach allows themes to emerge directly from the content, ensuring the analysis remains grounded in the actual material^[17]. By uncovering underlying themes that are not readily apparent through quantitative analysis alone, this method aligns with the study's objective to provide a comprehensive understanding of the research landscape, thereby bridging the gaps between quantitative trends and qualitative insights.

3.3. Data Collection Procedure

A robust data collection and analysis process underpinned the reliability and validity of this research. The Scopus database was chosen for its extensive coverage of the Social Sciences, outperforming alternatives such as Web of Science and Dimensions^[18]. Using a single comprehensive database avoided the complexities of integrating data from multiple sources^[19]. The PRISMA methodology ensured a meticulous data collection process involving initial search, screening, and eligibility assessments. **Figure 1** outlines the data collection procedure, including the search, screening, and eligibility stages. Specific criteria for the study's scope were applied during screening, refining the dataset for analysis. The initial search identified 840 documents using keywords such as “vocabulary knowledge,” “vocabulary depth,” “vocabulary size,” “vocabulary breadth,” and “vocabulary

development,” combined with “EFL” and “ESL.” After refining the results based on publication stage, subject areas, document types, and language, 720 relevant documents remained. Further exclusions, such as documents from 2024 and those unrelated to higher education or first-language students, reduced the final dataset to 601.

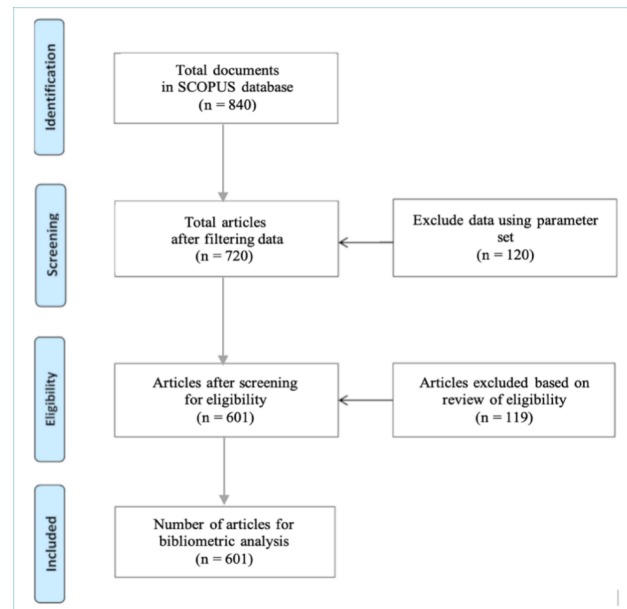


Figure 1. Data collection Procedure.

3.4. Data Analysis

For the three research questions, the design of this research study employed a mixed-methods approach, using descriptive statistics and science mapping in conjunction with qualitative content analysis. The selection of each analysis was tailored to align with the goals of the review. An overview of the analytical methods is presented in **Table 1**.

Table 1. Data Analysis Process.

Research Question	Description	Analysis	Outcome
1. Publication Trends and Major Research Themes	Descriptive statistics	Number of documents	Publication trends
	Science mapping	Bibliographic coupling analysis of documents and content analysis	Major research themes Common research themes Overarching themes
2. Characteristics of the Research Community	Descriptive statistics	Number of documents	Top contributing countries Leading contributing authors
		Number of citations	Top-cited documents
	Science mapping	Co-author analysis	Countries' collaboration Research groups and collaborative networks
		Bibliographic coupling analysis of sources	Publication scopes

Table 1. *Cont.*

Research Question	Description	Analysis	Outcome
3. Influential sources and journals, Emerging Research Gaps and Directions	Descriptive statistics	Number of journals Frequency of keywords Number of emerging themes	Top journals Top keywords Future research directions
	Science mapping	Bibliographic coupling analysis Co-word analysis Emerging trend analysis	Source impact and influence Emerging keywords Key research gaps

For RQ1, descriptive statistics were used to investigate publication patterns over the years, as well as the most productive countries, influential authors, and highly cited papers in the area. Co-authorship and bibliometric coupling of sources provided a network map of researchers and higher-order structuring of publications, respectively, to identify clusters of related research. Regarding RQ2, we employed descriptive statistics to identify the most influential journals in the field of vocabulary development research. Through bibliographic couplings of sources, journal impact, and reach were analyzed. This was augmented by content analysis, which illuminated thematic directions and concept overlaps within the leading articles, thereby enhancing subtle understandings of the intellectual terrain. To answer RQ3, descriptive statistics were used to track the frequency of new terms and research topics emerging. Finally, co-word analysis was conducted to identify themes and explore the conceptual structure of the field. Subsequently, trend analysis was used to identify emerging themes and research lacunae with an interpretation and implications for future research.

Content analysis was applied in the study of the qualitative aspects of the researched themes. This method facilitated the interpretational analysis of the findings by identifying the substantive, methodological, and contextual themes across the literature. Taken together, these analytic methods provide an integrated and methodologically rigorous portrait of the development, trends, and directions of research within the field of vocabulary learning in EFL/ESL higher education.

4. Findings and Discussion

4.1. Publication Trends and Key Contributors in EFL/ESL Vocabulary Development Research from 1984 to 2024

To address RQ1, this paper employed descriptive statistics and bibliographic coupling analysis to trace the trajectory

of EFL/ESL vocabulary development research over the four decades from 1984 to 2024. These strategies were employed to map presenting trends, historical changes in research focus, and important authors who have helped to advance the field. Mapping the development of scholarship and the influence of contributors, the study serves as an essential piece of the puzzle in understanding how the profession has responded to shifts in institutional priorities and technological changes, laying the groundwork for comprehending the intellectual development and transformation of the field.

4.1.1. Publication Trends from 1984 to 2024

The analysis of the publication trends in EFL/ESL vocabulary development research between 1984 and 2024 revealed a marked and sustained increase in scholarly activity. As illustrated in **Figure 2**, this growth can be categorized into three distinct phases, reflecting broader shifts in pedagogical focus, research methodologies, and technological integration within the field.

Phase 1 (1984–2008) is a period marked by limited research. In this early phase, academic productivity was limited to fewer than five papers per year. This phase represents a small proportion (5.66%) of the entire data set, suggesting that vocabulary as a field of study has not been a central topic within EFL/ESL, at least at this stage. However, two early reports^[5,20] effectively defined the field by the early 1990s. They defined and explained the notions of vocabulary size, depth of word knowledge, and the receptive/productive distinction in word knowledge. Although partial, the theoretical foundation established at the time was essential for future research.

Phase 2 (2009–2018), growth and diversification. Phase 2 is characterized by growth and diversification. This phase accounts for approximately 37% of the dataset and features annual publications with a range of 11 to 31 articles. This surge in research coincides with a growing global interest in second language acquisition, as well as the emer-

gence of innovative instructional methods and technologies. Researchers focused more on vocabulary learning strategies and pedagogical approaches, and many of them attempted to incorporate technology into their research. It was during this period that we observed a tendency for research to go beyond the theory, with a greater focus on the application of CALL, MALL, and online learning contexts. The broadening of research topics and settings in this period mirrors the larger movement toward more applied, evidence-based vocabulary instruction.

During the 2019–2024 period (Phase 3), there was a sharp expansion and a shift in themes. This last phase represents 56.57% of the dataset, with yearly publications from 60 to 90. The increase in research productivity reflects a growing awareness of the importance of vocabulary learning as a crucial component of language learning and academic achievement in EFL/ESL settings. At this stage, knowledge is becoming increasingly interdisciplinary and technological. Research has focused on multimedia, mobile applications, artificial intelligence (AI), and adaptive learning systems in vocabulary instruction. These developments not only embody changes in the way instruction is delivered, but they also allow for alternative forms of tailored and autonomous language learning. Moreover, the increasing use of big data and bibliometric techniques suggests a more systematic and evidence-based approach to studying vocabulary development.

Finally, the transition through these three eras reveals the evolving nature of the burgeoning field of vocabulary development research over the last forty years. Vocabulary research in EFL/ESL higher education has grown from its embryonic beginnings to its present vibrant, technology-infused maturity. This trajectory highlights the field's responsiveness to evolving educational needs and technological advancements, as well as the research and design spaces.

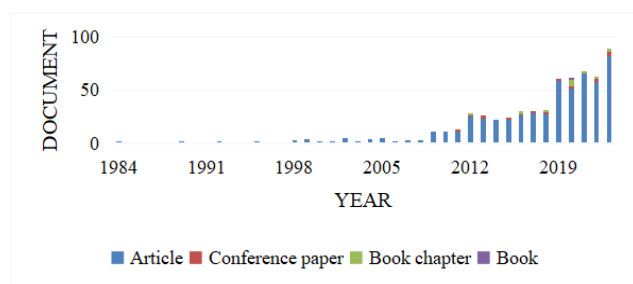


Figure 2. Annual Publication Trends.

A bibliographic coupling approach, combined with descriptive statistics, provided insight into the conceptual structure by examining clusters with common references and detecting thematic trends over time. In the first period (1984–2008), research focused on fundamental concepts, including vocabulary size, lexical richness, and the distinction between passive (receptive) and active (productive) vocabulary. Classical works from this phase^[1,3] provide the theoretical foundation for core concepts of modern vocabulary research. With the growth of the field from 2009 to 2018 (Figure 2), a substantial portion of the research focused on methodological and technologically innovative practices, including the rise of multimedia-assisted language learning, gamification, and mobile-assisted language learning. Influential input during this period^[21,22] shifted the emphasis toward incorporating digital tools and adaptive technologies into instructional design, with thematic strands that indicated a focus on improving vocabulary acquisition through enjoyable, learner-centered approaches. The research focus shifted during 2019–2024 more toward contextual and incidental vocabulary learning, facilitated through digital platforms, authentic language input, and AI-based personalization. Recent work^[23,24] exemplifies this shift and demonstrates how developing technologies have the potential to provide scalable, personalized vocabulary instruction. In sum, the bibliographic and publication growth patterns indicate a field at the stage of maturation and diversification as it progresses from foundational theory-building to applied, technology-enhanced instruction. This course reflects the design response to the changing demands of education and advances in technology. Yet, there are also essential lacunae, particularly in assessing the long-term efficacy and scalability of such innovations across diverse learning conditions. As the field advances, both longitudinal research and transdisciplinary teamwork, along with advances in technology, should inform future research on leveraging vocabulary teaching and learning in higher education.

4.1.2. Key Contributors in EFL/ESL Vocabulary Development Research (1984–2024)

An examination of the major contributors to EFL/ESL vocabulary development research can provide a rich account of how the field has grown over the last 40 years. This overview not only identifies the authors and institutions that have driven research but also reveals patterns of collabo-

ration and regional trends that shape the global discussion. As practitioners have no opportunity to receive knowledge about contribution trends in different countries or by other researchers, we are unable to understand the geographic, cultural and methodological diversity of vocabulary research in EFL/ESL higher education and its pedagogy.

A country-level contributions analysis (**Figure 3**) revealed 44 countries involved in this research area. Iran ranked top with 126 papers, playing a semi-central role in co-authorship networks with Malaysia, Indonesia, and Turkey. These collaborations represent common educational objectives and regional dedication to enhancing EFL vocabulary teaching. With 58 published articles, China took second place as a significant contributor, reflecting a broad collaboration with Asia, in particular Taiwan and Hong Kong. The United States was also a key player (53 publications), with strong international links with the UK, Hong Kong, and Canada. Such collaborative work has been productive in encouraging a variety of methodological and theoretical perspectives.

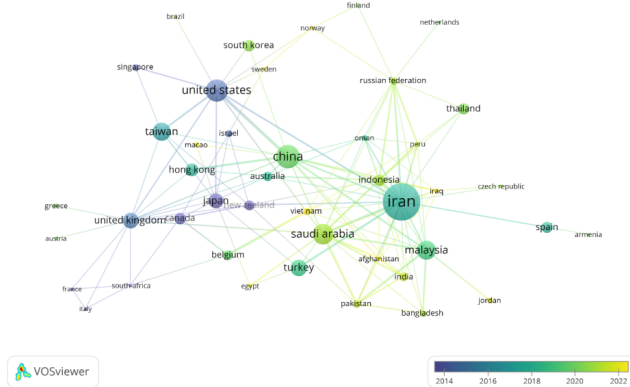


Figure 3. Countries' Collaborations.

Table 2 also presents the top 10 contributing countries, reflecting a geographically broad range of research leaders. In terms of theme-specific publication volume, Iran was at the forefront, with China and the USA in close pursuit. Both countries modelled the data heterogeneously; China concentrated on digital and mobile-assisted vocabulary learning, while the USA focused on theoretical innovation and methodological progress. The other major contributors were KSA, Malaysia, and Taiwan, which once again highlighted the growing role of the Middle East and Southeast Asia in global EFL research. The UK, Japan, and Hong Kong held firm, with their long histories in applied linguistics and EdTech. Furthermore, authors from Canada and Italy demonstrated a high academic influence, characterized by high citation densities, despite their lower publication outputs, in terms of their global research impact.

However, as appears from the data visualization (**Figure 4**), these countries tend to cluster in certain regions to collaborate with their regional partners, in a strategic manner for the advancement of the field. The Middle East and Southeast Asia node comprises Iran, Saudi Arabia, and Malaysia, characterized by significant regional cooperation and a focus on instructional innovation in multilingual environments. A Tri-directional cluster: East Asia (China, Taiwan, and Japan): A focus on technology integration in vocabulary learning. Meanwhile, the Western cluster, the U.S., UK, and Canada, continued to fuel theoretical and assessment research. Recent partnerships between countries like Pakistan, Indonesia, and Singapore are indications of a 51 more diverse global research community. Countries such as Belgium, the Netherlands, and Singapore played a crucial role in bridging the Western and Asian viewpoints, facilitating more comprehensive knowledge transfer.

Table 2. Top 10 Countries/Regions with High Research Productivity and Substantial Academic Impact.

ID	Country	Documents	ID	Country	Citations
1	Iran	126	1	Canada	1379
2	China	58	2	Italy	1198
3	United States	53	3	Oman	1186
4	Saudi Arabia	46	4	Iraq	889
5	Malaysia	41	5	Jordan	809
6	Taiwan	37	6	Thailand	687
7	Turkey	32	7	India	685
8	United Kingdom	29	8	Belgium	574
9	Japan	27	9	China	538
10	Hong Kong	21	10	South Korea	396

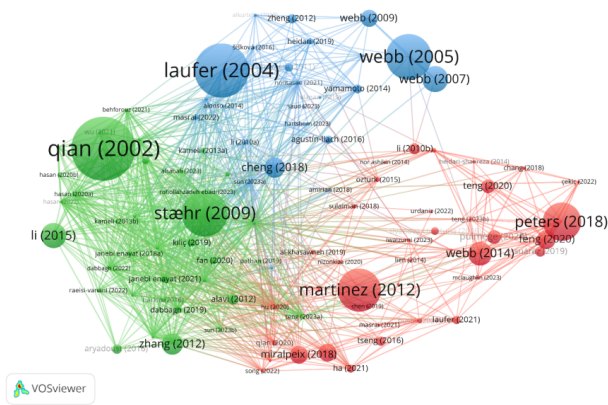


Figure 4. Research Groups and Collaborative Networks.

The cluster map (**Figure 5**) indicates that the research group is dynamic, with researchers from all groups interconnected. Different clusters were based on co-author patterns, citation relations and thematic orientation. Stuart Webb is one of the top researchers in the field, covering vocabulary learning strategies, multimodal learning, and the interaction between receptive and productive vocabulary knowledge. Another influential focus emerged with the work of Batia Laufer, who first examined vocabulary size, lexical richness, and procedures for measuring these concepts. Elke Peters also headed the notable group, which focused on incidental vocabulary learning and the role of multimedia exposure in language acquisition. These clusters reflect both ongoing academic cooperation, thematic focus, and methodological diversity, bringing together scholars from the U.S., China, Iran, and Europe in common lines of enquiry.

As shown in **Table 3**, the top contributors achieve a good trade-off between research productivity and academic impact. Stuart Webb is known for his significant contribution

to vocabulary learning strategies and his leadership approach in developing digital learning tools. Batia Laufer is recognized for her pioneering work on vocabulary testing and her theory of vocabulary learning. Elke Peters has made significant contributions to the field of incidental learning and technology-based vocabulary instruction. Academics such as David Qian and Paul Nation have made essential contributions to expanding our understanding of vocabulary depth and acquisition strategies. More recent voices, including Ahmed Masrai and Dongbo Zhang, have gained prominence with their original, cognitively informed insights. The community of researchers who have come together to work on this project is an extension of the authors' respective research networks, reflecting the reality that the research community is international and committed to understanding the changing facets of language education.

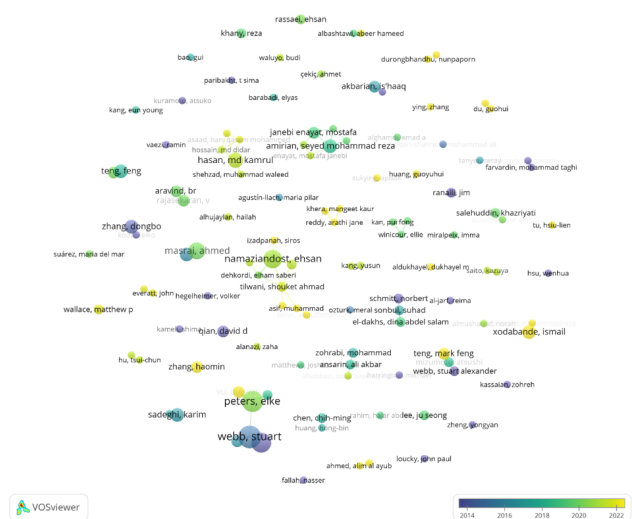


Figure 5. Research Community.

Table 3. Top 10 Influential Authors.

ID	Author	Affiliation	Documents	ID	Author	Affiliation	Citations
1	Webb, Stuart	University of Western Ontario, Canada	11	1	Laufer, Batia	University of Haifa, Israel	1584
2	Peters, Elke	Ku Leuven, Belgium	10	2	Webb, Stuart	University of Western Ontario, Canada	933
3	Laufer, Batia	University of Haifa, Israel	9	3	Qian, David D.	Hong Polytechnic University, Hong Kong	840
4	Namazandost, Ehsan	Islamic Azad University, Iran	8	4	Nation, Paul	Victoria University of Wellington, New Zealand	733
5	Marai, Ahmed	Prince Sattam Bin Abdulaziz University, Saudi Arabia	7	5	Peters, Elke	Ku Leuven, Belgium	563

Table 3. Cont.

ID	Author	Affiliation	Documents	ID	Author	Affiliation	Citations
6	Zhang, Dongbo	Michigan State University, United States	5	6	Schmitt, Nobert	University of Nottingham, United Kingdom	380
7	Teng, Feng	Hong Kong Baptist University, Hong Kong	5	7	Goldstein, Zahava	University of Haifa, Israel	326
8	Milton, James	Swansea University, United Kingdom	5	8	Zhang, Dongbo	Michigan State University, United States	286
9	Xodabande, Ismail	Kharazmi University, Iran	5	9	Paribakht, T. Sima	University of Ottawa, Canada	268
10	Sadeghi, Karim	Urmia University, Iran	5	10	Stæhr, Lars Stenius	University of Copenhagen, Denmark	261

To conclude, the EFL/ESL vocabulary development research community has evolved into a vibrant, collaborative, and geographically distributed constellation. Distinguished scholars were the pioneers in setting the field on a firm ground, and new scholars are still developing and exploring its theoretical, methodological, and technological edges. Results of country-level and author-level analyses indicate that international cooperation, interdisciplinary influences, and a shared understanding of the importance of sufficient vocabulary instruction in various educational settings increasingly mark the field. In the future, the development of such international partnerships, with a greater focus on supporting fair research participation across regions and collaboration linking countries worldwide, will be an essential strategy for driving growth and sustaining relevance in an increasingly changing educational environment.

4.2. Influential Sources, Journals and Themes in EFL/ESL Vocabulary Research (1984–2024)

To address RQ2, “Which journals, sources, and themes have been most influential in EFL/ESL vocabulary development research?” analysis was conducted using descriptive statistics and bibliographic coupling. Identifying these influential elements was crucial for understanding the field’s evolution and the factors driving its growth. By examining how specific publications and research areas have shaped academic discourse, guided methodologies, and influenced educational practices over the past four decades, it is possible to identify how these factors have impacted academic discourse, informed methodologies, and influenced educational practices. This analysis also revealed gaps and emerging trends, providing a roadmap for future research.

4.2.1. Influential Sources and Journals

The review of key journals and sources of publication in EFL/ESL vocabulary research from 1984 to 2024, conducted through descriptive statistics and bibliographic coupling, revealed a dynamic and increasingly complex scholarly communication environment. Impact was measured in multiple ways, including the number of citations, the impact factors of journals, publication quantity, and the degree to which journals have influenced the intellectual direction of the field. This multifaceted perspective enabled a detailed understanding of how academic journals addressed theoretical, methodological, and pedagogical issues related to vocabulary development.

Figure 6 illustrates the leading journals in *Applied Linguistics*, *Studies in Second Language Acquisition*, *Language Learning*, and *Applied Linguistics* consistently appear as the core forums for high-impact research. These journals have a well-established reputation for rigorous peer review and for their focus on publishing theoretically informed and methodologically rigorous papers. Yet their continued hegemony also calls for introspection about how the concentration of influence might limit intellectual diversity by further stabilizing dominant paradigms. Recent developments of journals (i.e., *Computer-Assisted Language Learning* and *Language Teaching Research*) also indicate a disciplinary move towards technology in language teaching in recent years. The growing number of technology-related publications signifies an expansion of research focus from the conventional classroom-driven research to the study of digital, mobile, and AI-supported vocabulary learning. This transition also posits new questions of research orientation, sustainability, and equity in technology-mediated learning spaces.

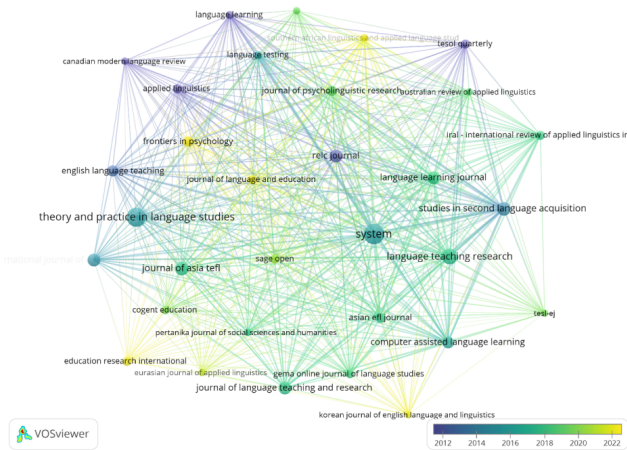


Figure 6. Major Sources of Journals.

The citation impact of journals also offers an additional

perspective of their academic impact. **Table 4** indicates that *Applied Linguistics* (with 1,655 references) is the most cited, followed by *Studies in Second Language Acquisition* (1,265 references) and *Language Learning* (929 references). These numbers affirm the influential role that journals play in the public perception. Yet one should be careful not to read too much into citation counts alone, which can be easily manipulated by a few highly-cited papers, and are not always a full measure of scholarly importance. System published the most papers (22) but received only 783 citations, indicating a discrepancy between the number of publications and citation impact. This inconsistency may suggest that numbers do not accurately reflect influence, and it again emphasises the importance of considering both quantitative and qualitative indices when evaluating the significance of a journal.

Table 4. Top Sources and their Scopes in EFL/ESL Vocabulary Research.

ID	Source	Scope	Documents	ID	Source	Scope	Citations
1	System	Applied linguistics, language education	22	1	Applied Linguistics	SLA	1655
2	Theory and Practice in Language Studies	Language teaching and research	20	2	Studies in Second Language Acquisition	SLA	1265
3	Language Teaching Research	Language teaching and applied linguistics	15	3	Language Learning	Language education	929
4	Second Language Acquisition	SLA	12	4	System	Applied linguistics, language education	783
5	Journal of Asia TEFL	Language education in Asia	12	5	Language Teaching Research	Language teaching and applied linguistics	584
6	RELC Journal	Language education in Southeast Asia	11	6	Canadian Modern Language Review	Language education	525
7	Language Learning Journal	Language education	11	7	RELC Journal	Language education in Southeast Asia	350
8	Journal of Language Teaching and Research	Language teaching and research	11	8	Computer-Assisted Language Learning	Technology in language education	329
9	International Journal of Applied Linguistics and English Literature	Applied linguistics, English literature	11	9	Language Testing	Language assessment	318
10	Computer-Assisted Language Learning	Technology in language education	10	10	Applied Linguistics	Psycholinguistics	261

Interconnections among the core journals are also shown in **Figure 6** and **Table 4**. The research network comprises Applied Linguistics, Studies in SLA, and System, three central nodes that connect research focusing on different themes within the field of vocabulary development. The

addition of regionally centered journals, such as *the Journal of Asia TEFL* and *the RELC Journal*, suggests a greater awareness of the need to consider localized perspectives in global language education. These journals offer valuable insights into regional challenges, culturally relevant teaching

methods, context-bound vocabulary instruction, and topics such as non-Western contexts and specific online foreign or additional language instruction.

A thematic analysis of these sources identified five main research scopes that have shaped the area's evolution. The first scope, *Vocabulary Acquisition and Teaching Methods*, includes journals such as *Language Teaching Research* and *Studies in SLA*. These journals focus on teaching methods, explicit teaching techniques, and learner engagement. The second, *Technology Integration in Language Education*, is run by *Computer-Assisted Language Learning and System*, and includes studies on digital tools, mobile applications, gamification, and AI in vocabulary learning. The third scope, *Applied Linguistics and Language Education*, encompasses more general ones such as *Applied Linguistics* and *Language Learning*, which explore multidisciplinary approaches to secondary language learning, language use, and educational applications. The fourth scope, *Regional Perspectives*, is represented by journals such as the *Journal of Asia TEFL* and *RELC Journal*, which provide a platform for context-based studies in Asia and other underrepresented regions. Finally, the fifth scope, *Psycholinguistics and Cognitive Approaches*, encompassing *Applied Psycholinguistics* and *Language Testing*, examines the mental processes involved in vocabulary learning and the validity of vocabulary tests.

Taken together, these results reflect a dynamic and broadening research environment. Despite the continued centrality of venerable journals to the field, newer, more specialized publications are gaining prominence, especially in areas involving digital and multimodal learning. The existence of these traditional and emerging journals demonstrates the evolution of what even traditionalist practitioners understand to be a disciplinary identity that oscillates between (and indeed reconciles) theoretical stringency/semantic stability and applied relevance, and is committed to technological innovation on the one hand, and the most firmly grounded linguistic cartographic principles on the other. This development is creating new paths for vocabulary development research, laying the ground for cross-disciplinary cooperation and more context-specific studies.

Overall, understanding patterns of journal power is crucial for researchers to make high-quality contributions to EFL/ESL vocabulary research. The results of this examination suggest where to publish, and which sources are

influencing current discussions and the practices associated with method development. Suppose scholars can selectively partner with influential journals and focus on new areas of research. In that case, they can place their work where it will be read not only by bond researchers but by educators across the spectrum of education, thereby leading them to adopt elements of evidence-based vocabulary instruction.

4.2.2. Major Research Themes

A comprehensive bibliometric analysis, incorporating co-word analysis and thematic mapping, was conducted to identify the major research themes in EFL/ESL vocabulary development between 1984 and 2024. This approach uncovered a wide range of interconnected themes, spanning foundational issues such as vocabulary size and lexical richness, to more contemporary developments involving the integration of technology into vocabulary learning. The thematic diversity reflects the field's expansion and responsiveness to both theoretical advancements and pedagogical innovations. **Figures 4 and 6**, along with the top 10 most cited documents, highlight key thematic areas that have shaped the research trajectory and methodological landscape of the discipline.

The first central theme, *Vocabulary Size and Lexical Richness*, explores the relationship between learners' vocabulary breadth and their language proficiency. Studies in this area^[1,25] emphasize the role of vocabulary size in both written and spoken production, highlighting the importance of lexical diversity in second language development. This theme has provided a foundation for measuring language ability and has informed the design of instructional strategies aimed at expanding learners' lexical resources.

The second theme, *Vocabulary Knowledge and Academic Performance*, focuses on the impact of vocabulary proficiency on learners' academic success, particularly in reading and listening comprehension. Research in this area^[26-31] has demonstrated strong correlations between vocabulary knowledge and reading ability, as well as vocabulary's predictive power in advanced listening comprehension. This line of inquiry has underscored the significance of vocabulary instruction in academic settings and contributed to the refinement of curriculum standards in higher education.

Testing and Assessing Vocabulary Knowledge constitutes the third prominent theme. This area examines methodologies for evaluating vocabulary size, depth, and strength, including the use of computer-adaptive assessments and di-

agnostic tools^[32,33]. These studies have been instrumental in establishing reliable and valid instruments to assess learners' vocabulary development and have contributed to best practices in language testing and evaluation.

The fourth theme, *Incidental Vocabulary Acquisition*, investigates how learners acquire vocabulary through unintentional exposure in natural contexts such as reading and multimedia engagement. Key studies^[20,21] have shown that incidental learning through L2 television and reading supports long-term retention and contextual understanding. This research highlights the importance of input-rich environments and has led to the integration of extensive reading and multimedia resources into language instruction.

Productive and Receptive Vocabulary Learning, the fifth theme, addresses the balance between vocabulary that learners can actively use (productive) and words they can recognize and understand (receptive). Studies^[34,35] illustrate the importance of both types of learning for comprehensive vocabulary development, emphasizing the pedagogical need to engage students in activities that promote both recognition and use.

The sixth theme, *Vocabulary Learning Strategies*, examines the cognitive and metacognitive techniques that learners employ to acquire new vocabulary. Research in this area^[22,36] has documented the effectiveness of strategies such as using phrasal expressions, contextual guessing, and word mapping, showing how strategy training can support autonomous learning and individual learner differences.

One of the most rapidly developing themes is *Technological Integration in Vocabulary Learning*. Recent studies^[21,24] reflect a growing trend toward incorporating digital tools, such as mobile apps, online games, and AI-driven platforms, into vocabulary instruction. These approaches have been shown to improve learner engagement and support personalized learning; however, they also raise questions about sustainability, digital equity, and pedagogical coherence.

The final theme, *Measuring Vocabulary Knowledge*, focuses on tools and metrics used to track vocabulary acquisition and proficiency. This research^[26,32] emphasizes the importance of accurate, context-sensitive measurement in both formative and summative assessment settings. The outcomes have implications for classroom practice, curriculum design, and benchmarking language proficiency.

These themes collectively demonstrate the breadth and

depth of EFL/ESL vocabulary development research, encompassing both foundational linguistic concerns and innovative pedagogical directions. Notably, the thematic analysis revealed recurring focal points, such as vocabulary size, academic performance, and technology integration, that underscore the field's central priorities. However, the dominance of specific themes may also limit the exploration of more diverse or emergent areas of inquiry.

A critical reflection on the thematic landscape reveals both achievements and challenges. While the integration of technology has expanded instructional possibilities, it has also introduced concerns about over-reliance on digital tools and disparities in access. Similarly, the emphasis on testing and quantifiable outcomes has contributed to methodological rigor but may overshadow more nuanced, qualitative dimensions of vocabulary learning, such as affective factors or cultural context. The field's heavy orientation toward academic performance and assessment also risks narrowing the scope of inquiry and excluding research on informal, community-based, or learner-initiated vocabulary development.

In conclusion, the thematic analysis of EFL/ESL vocabulary development research from 1984 to 2024 reveals a dynamic and evolving field of study. Foundational themes such as vocabulary size and academic performance remain central, while newer areas, particularly technology-enhanced learning, are gaining prominence. Although these trends reflect the field's adaptability, they also signal the need for a more balanced and inclusive research agenda. Future studies should prioritize longitudinal designs, diversify research methods, and promote interdisciplinary collaboration to ensure a comprehensive and contextually responsive understanding of vocabulary acquisition in EFL/ESL contexts.

4.3. Emerging Research Themes and Directions for Future Studies

To address RQ3, "What are the emerging research themes and future directions in higher education EFL/ESL vocabulary development research?" a comprehensive analysis was conducted using descriptive statistics, co-word analysis, and emerging trend analysis. The goal was to identify key gaps and explore potential research directions that could shape future studies. Identifying these gaps was crucial for advancing EFL/ESL vocabulary development, especially in

higher education contexts. As educational practices and technologies evolve, research has had to adapt to remain relevant and responsive to the diverse needs of learners while pushing the boundaries of effective vocabulary instruction and acquisition.

4.3.1. Emerging Research Themes

As shown in **Figure 7** and summarized in **Table 5**, the review of emergent issues and central keywords reveals many themes that remain under-researched in EFL/ESL vocabulary development research from 1984 to 2024. The following themes are still underexplored in EFL/ESL vocabulary development research from 1984 to 2024. These results highlight a trend in research emphasis and provide guidance for future strategic research efforts. The above gaps, as identified by recent systematic reviews and keyword trend analysis, highlight the need for more in-depth and context-sensitive

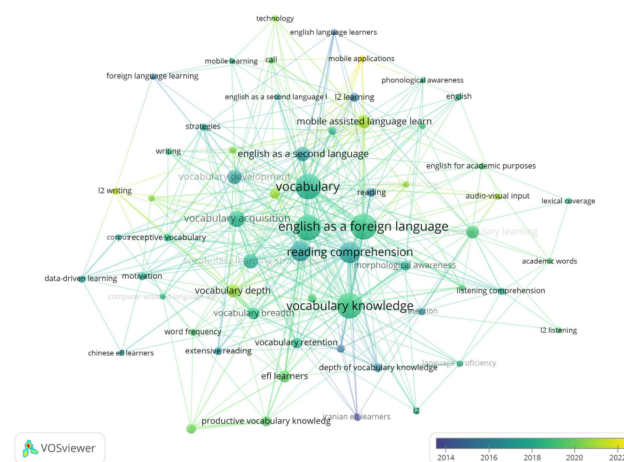


Figure 7. Research Themes and Topics.

Table 5. Top 10 Keywords.

ID	Keyword	Frequency	Avg. Year	ID	Emerging Keyword	Frequency	Avg. Year
1	English as a foreign language	56	2019	1	Mobile applications	5	2022
2	Vocabulary	55	2018	2	L2 writing	6	2021
3	Vocabulary knowledge	54	2019	3	Audiovisual input	6	2021
4	Vocabulary learning	54	2018	4	Mobile-assisted language learning	19	2021
5	Reading comprehension	40	2017	5	Academic vocabulary	12	2021
6	Vocabulary size	36	2017	6	Vocabulary depth	18	2021
7	Vocabulary acquisition	26	2018	7	Incidental learning	6	2021
8	Vocabulary learning strategies	22	2018	8	Technology	5	2020
9	Vocabulary development	21	2017	9	Structural equation model	6	2020
10	English as a second language	21	2017	10	Productive vocabulary	7	2020

Theme 1: Technology Integration and Vocabulary Learning

The frequency development of key terms such as “mobile application,” “digital tool,” and “audiovisual input” suggests a growing interest in using technology for vocabulary learning. Although the use of mobile-assisted language learning (MALL) and multimedia-enhanced settings has become increasingly prevalent, the literature offers only limited, longitudinal studies investigating the long-term consequences of these instruments on vocabulary acquisition, transfer, and learner independence. The current excitement around tech-integration needs to be measured by evidence-based research that can generalize to different pedagogies across diverse

learning environments, especially resource-poor environments.” It would also be helpful for the field to have more comparative studies examining the value of varying technology modalities on effectiveness at different times.

Theme 2: Contextual and Incidental Learning Approaches

A second significant trend would be emphasis on “incidental learning” and “contextual vocabulary acquisition,” reflecting a pedagogical shift toward naturalistic and meaning-based language input. Although incidental vocabulary learning through reading and media exposure works well, there is a need for empirical research to provide more evidence on the optimal conditions. Specifically, there is a dearth of

inquiry concerning how incidental learning can lead to productive language use (i.e., both spoken and written) and how contextual learning can complement formal instruction. The relationship between implicit learning and explicit instruction may lead to more effective patterns in the application of blended vocabulary teaching models.

Theme 3: Integrating Interdisciplinary Approaches

The growing occurrence of terms such as “academic vocabulary,” “productive vocabulary knowledge,” and “integrated skills” in the literature over the last few years is indicative of this view, as a greater understanding of vocabulary as a core feature of language use, and not simply a detached or marginal one, gains acceptance. This potentially ground-shifting paradigm situates vocabulary development not only as an isolated learning outcome but also as a key facilitator of communicative competence, academic achievement, and cognitive growth. Having said this, one significant limitation remains: research focusing on the intersection of vocabulary knowledge with other essential language skills, such as reading, writing, listening, and speaking, and with cognitive competencies, including critical thinking, metacognition, and academic discourse competence, reveals that knowledge is fragmented.

This disconnect leaves a timely and vital role for interdisciplinary work to locate vocabulary development within the larger context of language learning and academic success. Future studies might investigate how vocabulary development helps, and is in turn aided by, higher-level cognitive functions and production tasks that involve language, in actual academic and professional environments. For example, research could investigate how knowledge of academic vocabulary impacts students’ ability to construct cohesive arguments in writing, analyse texts, or engage in academic discourse. Likewise, studies that associate vocabulary learning with the use of metacognitive strategies and self-regulated learning may help gain a deeper insight into how learners control, monitor, and expand their lexical knowledge across various modalities.

Combining vocabulary with overall communicative and cognitive goals not only aligns well with learner-centered and task-based instructional models but also with models of language learning as a comprehensive endeavor. Such interdisciplinary views may contribute to the development of integrated curricula, in which vocabulary instruction is inte-

grated with content-based instruction, project-based learning, and genre-based academic tasks. This shift also has implications for assessment practices and the need for measures of vocabulary knowledge as part of learners’ broader language proficiency and academic performance, rather than in isolation.

In conclusion, research that establishes connections between vocabulary development and other language skills and cognitive domains represents a cutting-edge trend in the field. It encourages scholars and teachers to transcend conventionalist silos and embrace broader, evidence-based, complexity-informed perspectives on language learning in higher education. This interdisciplinary program of research offers the promise of practical knowledge, based on evidence, that may inform curriculum development and instruction, as well as promote learner engagement in EFL/ESL settings.

Theme 4: Shifting of Research Focus and Methodology

The appearance of method keywords “data-driven learning” and “structural equation modeling (SEM)” suggests the development of new, more advanced and data-related research designs in vocabulary research in this period. Although these techniques demonstrate that they can identify the interaction among variables, they are still not widely used. Further investigation is required to apply these approaches across different educational settings and learner groups. Additionally, several studies have integrated sophisticated methods with longitudinal data to examine the sustained effects of learning. This disconnect underscores the need for robust research designs that combine quantitative precision with longitudinal monitoring, thereby enabling a deeper understanding of the long-term effects of vocabulary instruction.

The top 10 traditional and emerging keywords were compared in **Table 5** to demonstrate the development trend of research interest over the last 40 years. The rise of technology-based, data-driven, and broad multidisciplinary terms demonstrates a field in flux, one that suggests an ascendancy of the macro unit of analysis over lower-order, disconnected word studies of the past.

In all, this paper identifies these emerging gaps in EFL/ESL vocabulary development research for future investigation. Closing these gaps will involve a deliberate emphasis on innovative approaches and extension of the range

of research settings and integrative teaching models. Taking an interdisciplinary perspective, establishing the long-term effectiveness of digital tools and the relationship between vocabulary and broader language competencies will be crucial for maintaining the field's importance and influence in a rapidly changing educational landscape.

4.3.2. Directions for Future Studies

Based on the research gaps identified, this study suggests several broad roadmaps that future research threads may follow in EFL/ESL vocabulary development. **Table 6** presents directions for future research, informed by the latest trends, technological developments, and new pedagogical demands, with a focus on promoting sustainable, inclusive, and science-based vocabulary instruction. These results suggest a shift away from single studies to more longitudinal, interdisciplinary, and context-specific research methods.

Trend 1: Initiating Longitudinal Studies

A longitudinal approach is essential for understanding how vocabulary learning changes and for estimating the long-term effects of instruction. Most studies conducted in the field are short-term, and as such, they provide a limited understanding of retention, transferability, and ongoing learner engagement. Future research could monitor students' vocabulary development longitudinally across semesters or school years to investigate the sustainability of their instructional effects as well as their use in both academic and out-of-school contexts of communication.

Trend 2: Expanding Technology Research

In the current context of high levels of internet, mo-

bile app and multimedia usage in vocabulary learning, it is imperative that the scalability, equality of access and efficacy of such tools are studied in various educational settings. Future research should incorporate more cross-cultural and comparative evaluations of the performance of technology-assisted vocabulary instruction across diverse sociolinguistic contexts and institutional environments. Such studies will be utilized to develop culturally responsive digital resources that are tailored to local needs.

Trend 3: Integrating Interdisciplinary Approaches

A comprehensive understanding of vocabulary learning necessitates an interdisciplinary approach to link vocabulary training with language and cognitive mechanisms. Further research should then investigate how vocabulary knowledge interacts with learners' reading comprehension, writing fluency, oral proficiency, and academic literacy. Drawing on conceptions and models from applied linguistics, cognitive science, and educational psychology, future research can develop integrated instructional models that are used in synergy, under the interdependence of language learning.

Trend 4: Enhancing Multimedia Learning

The multimedia approach to vocabulary learning is generating interest; however, there is a lack of comprehensive research on its optimal conditions. More research is needed to investigate how different types of multimedia (e.g., captioned videos, games, virtual reality) can support indirect and in-context vocabulary learning. The design of multimedia resources will benefit from an understanding of learner engagement, cognitive load, and the contribution of visual and auditory input.

Table 6. Directions for Future Research.

Theme	Document	Aim	Methods	Findings	Limitation	Future Research
1	Laufer (1995)	Explore lexical richness in L2 written production	Quantitative analysis of written texts	Vocabulary size correlates with lexical richness	Limited to written production	Investigate lexical richness in oral production
2	Qian (2002)	Examine the relationship between vocabulary knowledge and academic reading performance	Assessment perspective	Depth of vocabulary knowledge significantly impacts reading performance	Focused on academic reading only	Extend to other language skills (e.g., speaking, listening)
3	Webb (2005)	Investigate the effects of reading and writing on vocabulary knowledge	Experimental study	Both reading and writing activities enhance vocabulary knowledge	Short-term study	Conduct longitudinal studies to assess long-term retention
4	Peters (2018)	Examine incidental vocabulary acquisition through L2 television	Experimental study	Viewing L2 television facilitates incidental vocabulary acquisition	Limited to television viewing	Explore other multimedia resources (e.g., interactive games, virtual reality)

Table 6. *Cont.*

Theme	Document	Aim	Methods	Findings	Limitation	Future Research
5	Laufer (1998)	Investigate the development of passive and active vocabulary in an L2	Longitudinal study	The distinction between passive and active vocabulary is crucial for effective language learning	Focused on vocabulary only	Integrate with studies on other language components (e.g., grammar, pragmatics)
6	Stæhr (2009)	Examine the relationship between vocabulary knowledge and listening comprehension in EFL learners	Correlational study	Advanced vocabulary knowledge is crucial for listening comprehension	Limited to advanced learners	Include learners of different proficiency levels
7	Martinez (2012)	Develop a list of phrasal expressions for language learners	Corpus-based study	A phrasal expressions list aids in practical language learning	Lists may not be exhaustive	Expand the list and validate it across different contexts
8	Paribakht (1999)	Explore incidental L2 vocabulary acquisition through reading	Experimental study	Reading is effective but depends on various factors (e.g., frequency of exposure)	Short-term study	Conduct longitudinal studies to understand long-term effects
9	Peters (2018)	Examine factors affecting incidental vocabulary acquisition through L2 television	Experimental study	Several factors (e.g., repetition, context) influence the effectiveness of incidental vocabulary acquisition	Focused on television viewing	Investigate other multimedia resources
10	Laufer (2004)	Test vocabulary knowledge: size, strength, and adaptiveness	Quantitative assessment	Vocabulary size and strength are key indicators of language proficiency	Limited adaptiveness in testing	Develop more adaptive and context-sensitive testing methods

The results of this bibliometric analysis underscore the importance of developing a more comprehensive, prospective research agenda in EFL/ESL vocabulary development. These gaps necessitate a commitment to longitudinal investigations, interdisciplinary approaches, and culturally sensitive future research. By drawing upon these future directions, the field can be assured that vocabulary instruction will continue to be an efficient, responsive, and meaningful component of an ever-growing and evolving educational milieu.

5. Conclusions

The bibliometric analysis systematically investigated the development, current pattern, and future trends of vocabulary development research in EFL/ESL higher education between 1984 and 2024. Based on three orienting research questions, the study tracked publication patterns, prominent contributors and influences, and leading research themes that have shaped knowledge production in the field. The results demonstrated a significant and continuous growth in publishing research over the last two decades, driven by measures that increased the pedagogic significance of vocabulary

learning and the use of technology in language education.

The findings showed a shift away from traditional issues, such as vocabulary size and the differentiation between receptive and productive vocabulary, to more dynamic ones, including multimedia-supported learning, after-class or after-school applications, AI-supported teaching, and the role of academic vocabulary in the development of interdisciplinary or integrated capabilities. Key authors, such as Stuart Webb and Batia Laufer, along with other luminaries in the field, have shaped the field through extensive reading across nations and collaborative joint work. Iran, China, and the USA were seen as research centers, and regional collaborations with Saudi Arabia, Malaysia, and Taiwan highlighted the increasing internationalization of vocabulary research. To be sure, high-profile journals, among them *Applied Linguistics*, *Studies in Second Language Acquisition*, and *Language Learning*, were identified as pivotal to the field's intellectual growth and the dissemination of high-impact research.

This review also acknowledges its limitations. There are limitations to the analysis, however, such as being confined to the parameters of the Scopus database, which may re-

sult in the exclusion of influential articles from non-indexed or alternative journals, or the exclusion of researchers from non-dominant regions. Furthermore, although tremendous influence has been exerted by researchers (e.g., Averil Coxhead, Dee Gardner, Mark Davies) who made groundbreaking contributions to vocabulary in this time frame, the representation of these scholars in the present study was not substantial, most probably as a result of the institutional policies for indexing or since the study targeted only higher education settings.

To minimize these limitations, future research should adopt a comprehensive database method (e.g., Web of Science, ERIC, and Google Scholar), as well as consider grey literature. Secondly, future research should employ empirical examination methods that incorporate longitudinal and cross-cultural comparisons to more objectively assess the extended efficacy and maintainability of instructional strategies in vocabulary teaching. There is also an urgent call for empirical enquiries to determine the development and relationship of vocabulary learning to broader language learning skills (such as writing, speaking, and academic language) and across various content areas, and to adopt an interdisciplinary and data-driven approach.

Overall, this bibliometric review provides a state-of-the-art overview of the four decades of research into EFL/ESL vocabulary development, offering essential information regarding the history, present state, and future direction of this area of research. Through the identification of the salient trends, influential scholars, and emerging issues identified in the present study, this work provides a springboard for the promotion of research that aims to be pedagogically meaningful, methodologically rigorous, and inform appropriate decision-making on a global scale, in hopes of improving more effective and equitable vocabulary instruction for learners of modern languages in tertiary education.

Author Contributions

Conceptualization, T.T., A.S., and P.P.; methodology, T.T. and A.S.; formal analysis, T.T. and A.S.; data collection, T.T.; writing, original draft preparation, T.T.; writing, review and editing, A.S. and P.P.; supervision, A.S. and P.P. All authors have read and agreed to the published version of the

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This research did not require IRB approval.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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