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A Bibliometric Analysis of Deep Learning-Based Reading Instruction Models for EFL Students (2015–2025)

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ABSTRACT

This study presents a bibliometric analysis of research on deep learning (DL)-based reading instruction models for English as a Foreign Language (EFL) learners published between 2015 and 2025. The rapid advancement of DL technologies has reshaped instructional strategies in language education, comprehensive insights into their application in EFL reading remain limited. The study aims to map global research trends, identify influential authors and sources, examine collaborative networks, and explore thematic development in the field. Data were retrieved from the Dimensions AI database using targeted keyword searches and analyzed with VOS viewer. Results indicate a sharp increase in publications after 2019, with emphasis on classroom applications, such as personalized learning, feedback, and student motivation. Highly cited works appeared in interdisciplinary journals, including Sustainability and Computers & Education: Artificial Intelligence. Co-authorship analysis revealed strong regional clusters in China, the United Kingdom, and Southeast Asia, while Indonesia emerged as a growing contributor with limited international collaboration. Keyword co-occurrence analysis highlighted dominant themes including assessment, self-efficacy, and integration. Despite rising research interest, significant gaps remain in localized applications and accessibility of DL tools in developing contexts. The findings

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underscore the need for Indonesia to strengthen its research presence by developing scalable, culturally relevant DL models and fostering international partnerships. This study contributes to the field by offering a comprehensive overview of scholarly development and by identifying future directions for AI-supported reading instruction in EFL education.
Keywords: Deep Learning; Reading Instruction; EFL Learners; Bibliometric Analysis

1. Introduction

In the past decade, deep learning (DL) has profoundly reshaped the landscape of educational technology, offering innovative solutions for personalized learning, instructional automation, and learner engagement across diverse contexts[1,2]. As a subset of machine learning, DL employs multi-layered artificial neural networks- such as Convolution Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Long Short-Term memory (LSTM) models — to process large — scale and complex educational data. These models simulate brain-like learning processes and enable sophisticated tasks like pattern recognition, natural language understanding, and semantic feature extraction, thereby laying the foundation for advanced learning systems that respond to individual differences in student ability, motivation, and engagement[3,4].

The educational applications of DL are rapidly expanding to support intelligent tutoring systems, speech-to-text tools, adaptive content generators, and automatic feedback systems all of which contribute to an ecosystem of highly responsive and personalized instruction[5,6]. These capabilities are particularly valuable in English as a Foreign Language (EFL) learning environments, where learners face unique challenges, including differences in orthography, syntax, and pragmatics. Reading, as a critical literacy skill, serves as a foundational element in EFL acquisition. It supports vocabulary growth, syntactic processing, academic literacy, and cross-cultural comprehension[7,8].

However, despite the centrality of reading in EFL contexts, traditional instructional methods often lack the flexibility to address the heterogeneous needs of learners. Many classrooms operate under rigid curricular structures and standardized assessments that fail to adapt to learner variability. This issue is exacerbated when considering learners with special educational needs or those from under-resourced environments[9,10]. DL-based systems, in contrast, are capable of dynamically modifying instructional pathways by integrating data from learner profiles, historical performance, reading behavior (e.g., eye-tracking, clickstreams), and even affective indicators[11–13].

For learners with learning disabilities (LD), especially in reading, DL offers even more transformative possibilities. Students with LD often face persistent struggles in comprehension due to deficits in phonological awareness, working memory, decoding, and inferencing skills[14–16]. Research has shown that explicit and metacognitive reading strategies such as summarizing, self-questioning and identifying text structures can significantly improve reading outcomes for these students[17]. DL enhances these evidence-based practices by integrating real-time feedback, multimodal scaffolding (e.g., audio narration, visual cues), and adaptive difficulty adjustments, all of which allow instruction to remain within the learner's zone of proximal development[15,18].

Moreover, DL-based reading instruction systems align well with the principles of Universal Design for Learning (UDL), a framework that advocates for multiple means of representation, engagement, and expression to cater to diverse learner profiles. For instance, DL can facilitate text-to-speech functionalities for students with decoding issues, generate interactive graphics for visual learners, and customize task formats to match learners' cognitive load capacities[19,20]. These affordances not only foster inclusivity but also support the development of learner autonomy and agency—key goals in modern language pedagogy.

Cognitive load theory further underscores the value of adaptive DL systems. In EFL reading, extraneous cognitive load may arise from unfamiliar vocabulary, syntactic complexity, or cultural content, making it difficult for learners to allocate cognitive resources to deeper comprehension[21]. DL systems reduce this burden by simplifying texts, breaking down complex syntax, and supporting word recognition with definitions or visual aids, thus optimizing intrinsic and germane cognitive load for better learning outcomes[22–24].

An additional strength of DL is its capacity to detect early warning signs of reading difficulties — especially criti-

cal in early education. Through the analysis of phonological processing data, decoding speed, and comprehension trends, DL models can identify at-risk learners with high levels of accuracy and suggest timely interventions [11,25]. Such predictive modeling supports early intervention frameworks like Response to Intervention (RTI), where data-informed tiered support can replace reactive approaches traditionally based on delayed failure detection [26].

Despite these advancements, the field still lacks a comprehensive understanding of how DL systems are being integrated into EFL reading instruction. Although the number of studies has grown substantially, current literature reveals methodological fragmentation and inconsistent reporting standards across studies [27,28]. There is an absence of systematic mapping studies that explore the specific intersection between DL and reading instruction in EFL contexts—particularly with respect to learners with LD and those in low-resource settings.

Bibliometric studies in other fields have proven effective in identifying research trends, scholarly impact, and international collaboration networks [29]. However, few such studies exist in this emerging domain. A systematic mapping is needed to uncover prevailing themes, research gaps, and potential interdisciplinary linkages between computer science, cognitive psychology, linguistics, and special education. Furthermore, there is an urgent need to explore the geographic distribution of this research. For instance, countries such as Indonesia are rapidly expanding their use of DL tools in education, yet remain underrepresented in global analyses [30].

Ethical concerns must also be addressed. DL models are often "black boxes," rendering their internal decision-making opaque to educators and learners. As Alqahtani et al. caution, without model interpretability, educational stakeholders may struggle to trust or act on the recommendations generated by these systems [31]. Issues related to data privacy, algorithmic bias, and equitable access to technology further complicate large-scale implementation in diverse educational settings [32,33].

At the instructional level, DL systems also hold promise for supporting teacher professional development. These tools can generate automated reports on learner progress, suggest pedagogical strategies, and simulate differentiated instruction scenarios [9,17]. In doing so, DL does not aim to replace the teacher but rather to augment teacher agency and decision-making through real-time insights and pedagogical modeling [34].

To fully realize these benefits, it is essential to move beyond experimental pilot studies and develop scalable, evidence-informed DL frameworks that are accessible to EFL teachers and learners across cultural and socioeconomic contexts. Thus, this study aims to address these gaps by conducting a bibliometric analysis of literature published between 2015 and 2025 on DL-based reading instruction for EFL learners. The specific objectives are:

1. To analyze publication trends and the growth of research in this domain.
2. To identify influential authors, journals, institutions, and countries contributing to this field.
3. To uncover dominant research themes and cultures through co-authorship, co-citation, and keyword network analysis.

By providing a comprehensive overview of scholarly developments, this study seeks to support future research and inform pedagogical practices at the intersection of DL and EFL reading instruction.

2. Literature Review

2.1. Deep Learning in Education

The integration of deep learning (DL) into education has fundamentally redefined pedagogical practices, learner engagement, and instructional delivery. Drawing upon architectures such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, and Graph Convolutional Networks (GCNs), DL technologies offer educators tools capable of real-time adaptation and learner-specific responses. CNNs, widely used for image and video recognition, are now leveraged to enhance visual content understanding in educational multimedia environments [35,36]. RNNs and LSTMs, on the other hand, are pivotal in language modeling and sequential data tasks, particularly effective in reading comprehension, sentiment analysis, and language learning applications [8]. These models enable systems to maintain memory over sequences, making them well-suited for tracking learner progress and predicting outcomes in educational timelines.

Regarding reading, a CNN facilitates the visual word recognition and orthographic processing by attending to local textual patterns, while an RNN or LSTM processes sequential relations in language for parsing sentences and understanding discourse-level constructs. By modelling the way that readers are sensitive to grapheme-to-phoneme correspondences, and how they put ideas together across sentences, these models mirror bottom-up decoding processes and top-down schema activation respectively. This synergy makes DL particularly powerful in helping users comprehend reading, since it aligns to both cognitive and metacognitive strategies that readers have adopted.

A key area of innovation enabled by DL is personalized learning, where instructional materials and feedback are dynamically tailored to match learners' cognitive, emotional, and behavioral profiles. Through real-time behavioral pattern analysis, DL systems can generate learning pathways that adapt in complexity and modality, thereby enhancing learner autonomy and motivation [37,38]. The application of emotion-aware DL systems—using facial expression, voice tone, and engagement level recognition—has proven particularly impactful in EFL (English as a Foreign Language) classrooms, where student affect is closely linked to language learning efficacy. Hu and Jin demonstrated the utility of reinforcement learning integrated with DL in constructing adaptive environments for English instruction, optimizing learner interaction based on reward-based behavior modeling [39]. This resonates with the schema theory's emphasis on the motivation and prior knowledge activation, as an emotion-aware system can lower affective filters and prime learners to connect texts with their existing mental frameworks.

Intelligent Tutoring Systems (ITS) represent one of the most promising applications of DL in education. These systems simulate human tutor functionalities, delivering individualized guidance and feedback at scale. ITS powered by LSTM and GRU (Gated Recurrent Unit) architectures can identify knowledge gaps and provide context-specific interventions [40–42]. For instance, Deep Tutor offers conversational feedback, continuously adjusting to student responses in real time [43]. Such systems are especially effective in supporting students with learning disabilities, as they offer multimodal support (text, speech, visuals), enable repetition without judgment, and provide scaffolds based on student responses [44,45].

Another critical function of DL is predictive analytics, which enables early identification of at-risk students and forecasts academic outcomes. LSTM networks trained on sequential learner behavior datasets, such as the API – Edu datasets, have achieved high prediction accuracy for engagement trends and performance trajectories [8,38]. Baniata et al. used GRUs to achieve 99.7% accuracy in predicting student performance, highlighting DL's power in supporting proactive academic interventions [42]. These systems assist educators in making informed decisions by flagging students who may benefit from additional support, thereby preventing learning loss and dropout.

DL also facilitates adaptive learning systems, where instruction and assessment are adjusted continuously based on student interaction data. Weike et al. describe adaptive platforms that analyze student clickstreams, quiz performance, and time-on-task metrics to fine-tune lesson pacing and content complexity [46,47]. These systems benefit from DL's ability to model non-linear, complex relationships in data—something traditional rule-based systems struggle to achieve. Additionally, DL enhances resource recommendation engines, curating personalized educational materials, including videos, articles, and simulations, based on learners' styles and preferences [48].

One of the most celebrated affordances of DL is its role in real-time feedback and automated assessment. DL, powered feedback systems offer immediate error correction, concept clarification, and hints during problem-solving tasks [38,49]. Such systems significantly reduce teacher grading time and allow for continuous formative assessment. Automated writing assessment tools, for instance, use NLP, enabling DL models to evaluate grammar, coherence, vocabulary, and content relevance, delivering near-human quality feedback [50]. The integration of these feedback and assessment functions can be more deeply understood through cognitive learning theory (CLT), which emphasizes the management of intrinsic, extraneous, and germane cognitive loads during learning. DL-based feedback mechanism helps regulate these loads by providing real-time, adaptive scaffolding that reduces unnecessary mental effort. When learners receive targeted hints or corrective input from systems such as LSTM-based tutors, they avoid extraneous distractions and focus cognitive resources on schema construction, precisely what CLT identifies as connected processing. In this regard,

the intelligent feedback loops designed in DL environments translate theoretical principles of CLT into practice, enabling optimized learning efficiency and sustained engagement.

Despite its vast potential, the application of DL in education is not without challenges. Interpretability remains a key concern. Neural network-based models often function as "black boxes," making it difficult for teachers and administrators to understand the reasoning behind predictions and recommendations [10,31]. This opacity can hinder trust and acceptance among educators, particularly in high-stakes assessment contexts. In addition, ethical concerns around data privacy and algorithmic bias are increasingly being raised. DL models trained on skewed datasets may inadvertently perpetuate educational inequalities, especially if they underrepresent students from disadvantaged or minority backgrounds [32,51].

The content of implementation also shapes DL's effectiveness. In Indonesia, studies reveal that infrastructural limitations — such as internet access, device availability, and cloud computing access — pose significant challenges to the widespread development of DL-based systems, particularly in rural schools [52,53]. Furthermore, the readiness of teachers to adopt DL-based instructional methods is a critical issue. Many educators lack sufficient training in AI-based tools and feel overwhelmed by the demand for digital pedagogy [54,55]. Yulianto argues that DL can only be effectively adopted in Indonesia if aligned with the Emancipated Curriculum's project-based and student-centered philosophy [56].

Globally, emerging models of hybrid instruction are combining DL with other innovations such as augmented reality (AR), gamification, and Universal Design for Learning (UDL). For example, adaptive reading platforms for children with learning disabilities now use DL to adjust story complexity and support multiple representation formats (audio, text, visual), in line with UDL principles [18]. In higher education, DL models are used to detect early signs of disengagement in Learning Management Systems (LMS) through activity monitoring and biometric data [12,48,57]. Moving forward, research must focus on creating interpretable, inclusive, and scalable DL models. Cross-disciplinary collaborations between educators, data scientists, and policy makers are crucial to ensure that these technologies serve pedagogical rather than purely technologies ends [58]. Studies should also explore the long-term impact of DL-based learning on learner autonomy, cognitive development, and metacognitive awareness [59]. As Esakkiammal & Kasturi note, sustainable innovation in education requires continuous evaluation, context-specific adaptations, and alignment with local curriculum standards [60].

2.2. Reading Instruction for EFL Learners

Reading is a foundational skill in English as a Foreign Language (EFL) education, playing a vital role in vocabulary development, grammatical awareness, and overall academic achievement [28,61]. As EFL learners often have limited opportunities to engage with the target language outside of the classroom, reading serves as a crucial input source for language acquisition and cognitive development [15,62,63]. Various models have been proposed to guide EFL reading instruction. The top-down model encourages the activation of schemata, prior knowledge, and context cues to construct meaning, thereby fostering critical thinking and inferencing skills [64–67]. In contrast, the bottom-up model emphasizes word recognition, phonemic decoding, and grammatical analysis, making it particularly suitable for beginners or learners with limited vocabulary. The interactive model combines these two, allowing learners to shift between decoding and higer-order processing depending on their needs and proficiency level [68,69].

Reading instruction can benefit from deep learning models, precisely because they augment traditional constructs of reading. For instance, according to schema theory, one of the keys is activating prior knowledge; this can be supported in DLL using multimedia glosses, visual supports or background information provided based on individual learners' cultural and linguistic context information while learning. Likewise, cognitive load theory focuses on minimising extraneous load to enable a better understanding of content. DL algorithms can automatically simplify texts, highlight target vocabulary, and modify sentence comprehension to direct a learner's cognitive resources towards relevant load—e.g., inferencing and meaning building. At scale, DL models implement these theoretical ideas, defining learning regimes as the interface between bottom-up decoding and top-down comprehension.

Effective reading instruction must address both cognitive and metacognitive strategy training to promote deep comprehension and learner autonomy. Cognitive strategies such as skimming, scanning, inferring meaning, and distinguish-

ing literal from implied content are frequently used to navigate EFL texts [34,70]. Meanwhile, metacognitive strategies—including planning, monitoring, evaluating, and reflecting—help learners regulate their reading processes and improve comprehension over time [71–73]. Research has consistently shown that learners who receive explicit instruction in both types of strategies demonstrate significantly higher reading performance and confidence [74,75]. Motivation also plays a critical role in reading development. Students who perceive success, receive targeted feedback, and read culturally relevant materials are more likely to persist in reading tasks [76]. Integrating extensive reading (ER) programs into instruction can promote a love of reading and build fluency through exposure to large volumes of comprehensible texts [77]. DL-based intelligent tutoring systems augment these strategies by offering adaptive prompts (for example, suggesting when to skim vs. when to reread) and metacognitive dashboards that visualize comprehension progress, thereby externalizing otherwise invisible reading processes.

Equally important is the recognition of prior knowledge as a key factor influencing reading comprehension. Based on schema theory, learners use their linguistic, conceptual, and sociocultural background knowledge to interpret and retain new information [78]. Linguistic knowledge (vocabulary, syntax), conceptual understanding, and cultural familiarity all contribute to successful comprehension, particularly when appropriately activated during pre-reading stages [79,80]. Teachers can facilitate this through brainstorming, discussion, visual aids, and background-building strategies [61]. However, activating prior knowledge is not without challenges, especially when learners possess limited linguistic competence or unfamiliarity with the topic, and when teachers lack training in schema-based pedagogies [61,81].

A significant barrier to effective reading instruction in the EFL context lies in the limited preparation of pre-service teachers. Many teacher education programs provide insufficient training in reading pedagogy, resulting in graduates who struggle with integrating reading strategies, designing inclusive instruction, and adapting materials for diverse learners [82–84]. Studies report that pre-service teachers often face difficulties managing mixed-ability classrooms, selecting culturally appropriate texts, and balancing fluency with accuracy [85,86]. The pressure of institutional constraints — such as curriculum overload, insufficient course duration, and limited access to quality reading materials — further complicates instructional planning [81,86]. To bridge these gaps, teacher training must include systematic exposure to reading strategy instruction, task-based learning, lesson planning, and reflective practice [87].

To address these challenges, many institutions implement multi-modal reading instruction that combines intensive reading (IR) for detailed analysis and extensive reading (ER) for fluency development [77]. Programs that blend both methods help learners improve comprehension while also fostering engagement and autonomy. Additionally, integrating reading and writing instruction—especially using thematic or content-based units—has been found to improve both skills simultaneously [88,89]. Communicative and task-based approaches further encourage meaningful interaction with texts, fostering real-world literacy and intercultural awareness. Successful curricula often apply the 6-Ts framework (topics, texts, themes, tasks, time, testing) to create balanced, engaging, and flexible reading instruction [89].

The integration of technology into reading instruction has also transformed how EFL learners interact with texts. Digital tools, such as e-books, AI reading assistants, and applications like Beelinguapp, offer personalized and interactive reading experiences that enhance comprehension and motivation [90–92]. Platforms that support bilingual reading, real-time feedback, or gamified content have shown promise in lowering affective filters and fostering learner engagement [63,93]. Moreover, virtual and augmented reality applications now provide immersive environments for context-rich reading experiences [94]. Despite these advantages, technology integration still faces challenges such as unequal digital access, limited teacher training, and the need for pedagogical alignment [95,96].

Furthermore, collaborative and literature-based strategies—such as Think-Pair-Share (TPS) and SQR3 (Survey- Question-Read-Recite-Review)—have been found to enhance reading comprehension and promote higher-order thinking in EFL learners [97]. These methods promote dialogic engagement with texts and allow learners to reflect, share perspectives, and build collective understanding. Such practices are especially beneficial when integrated with culturally relevant literature, as they foster empathy, identity affirmation, and deeper emotional connections [98]. Additionally, incorporating critical literacy frameworks into reading

instruction can help learners interrogate texts, question assumptions, and develop a more nuanced understanding of language and power [75].

Reading instruction for EFL learners is a complex, multidimensional practice that requires thoughtful integration of instructional models, learner-centered strategies, technological tools, and sociocultural awareness. Effective instruction balances top-down and bottom-up processing, integrates cognitive and metacognitive strategies, activates prior knowledge, and responds to learner motivation and background. Teacher training institutions must prioritize systematic preparation in reading pedagogy, provide access to diverse materials, and support ongoing professional development. Future directions point toward the increased use of personalized, technology-supported instruction, the integration of reading and writing, and a stronger emphasis on intercultural competence and learner autonomy. By adopting these practices, educators can cultivate not only proficient readers but also critically literate, globally minded language users.

The empirical findings reviewed above reinforce and operationalize the theoretical frameworks underpinning EFL reading instruction. Schema theory and cognitive load theory are reflected in studies showing that pre-reading activation, scaffolding, and contextualized vocabulary support significantly enhance comprehension and retention, especially among lower-proficiency learners. Likewise, evidence on cognitive and metacognitive strategy training substantiates the interactive model of reading, demonstrating that learners who alternate between decoding and meaning-making processes achieve greater fluency and comprehension gains. Findings on motivation and engagement align with affective dimensions of reading frameworks, highlighting how culturally relevant texts and adaptive digital tools reduce anxiety and sustain effort. Moreover, research on teacher preparation underscores the need to translate theoretical principles, such as balancing top-down and bottom-up processing, managing cognitive load, and activating prior knowledge, into pedagogical competence.

2.3. Integration of DL in EFL Reading Instruction

The integration of Deep Learning (Dl) technologies into EFL reading instruction marks a significant pedagogical advancement, offering personalized, data-driven, and efficient learning environments. DL-powered tools, such as adaptive reading applications and intelligent tutoring systems, can analyze learners' interaction patterns to deliver tailored reading material, real-time scaffolding, and individualized feedback [29]. These tools enhance differentiated instruction by adjusting reading complexity based on learners' vocabulary usage, reading speed, and comprehension patterns, thereby supporting learners with diverse proficiency levels and learning needs. Natural Language Processing (NLP), a key component of DL systems, allows for the automated evaluation of reading fluency, accuracy, and comprehension, helping educators efficiently identify learning gaps and monitor student growth over time [99]. These innovations reduce teacher workload while maintaining high assessment fidelity, especially in large or resource-constrained classrooms [100].

Empirical evidence confirms these affordances. For instance, Stranovska et al. indicated that extensive reading platforms assisted by DL enhanced EFL students' reading fluency and comprehension based on immediate matches between text difficulty levels and the individual ability of the learners. Likewise, Chien found that DL-based NLP tools gave "an accurate indication of reading fluency and accuracy, much closer to the actual performance than traditional assessments", which could help teachers track progress with more specificity. These results indicate that DL systems realize fundamental reading theories—schema activation, cognitive load reduction, and metacognitive monitoring—in scalable and context-adapted fashions.

However, the adoption of DL in EFL reading instruction is not without challenges. Equity-related issues — such as limited access to digital devices, unstable internet connectivity, and insufficient digital literacy among both teachers and students — can limit the effectiveness and inclusivity of DL integration [1]. Moreover, the opacity of DL algorithms, often referred to as the "black box" problem, raises concerns about transparency and the interpretability of assessment results.

Educators may find it difficult to trust or act upon data generated by systems they do not fully understand, which can weaken the pedagogical impact of these tools. Pedagogical alignments remain a critical factor in maximizing the potential of DL applications. DL tools must not merely serve as technological enhancements but should be embedded within a coherent instructional framework that aligns with learning

objectives, curriculum standards, and assessment strategies. To achieve this, teacher training programs must include both technical and pedagogical components, equipping educators with the competence to select, implement, and evaluate DL tools effectively in their reading instruction.

Ultimately, the integration of DL into EFL reading instruction holds the potential to revolutionize how learners engage with texts, develop comprehension, and receive feedback. When used appropriately, DL can support adaptive learning, enhance formative assessment, and create collaborative digital reading environments, all of which contribute to a more inclusive, responsive, and personalized reading experience. Nevertheless, its successful implementation hinges on institutional readiness, teacher preparedness, and a shared understanding of how technology can support, not replace, human-centered instruction.

2.4. The Role of Bibliometric Analysis in Educational Research

Bibliometric analysis is a systematic method for evaluating scholarly output, trends, and influence within a specific research domain. It involves the use of statistical and network analysis techniques to map publications, citations, co-authorships, and thematic clusters[101–103]. This approach helps researchers and educators understand how knowledge evolves and identify gaps, leading contributors, and emerging areas of interest. Several bibliometric studies have explored the role of artificial intelligence and DL in education. Beckett and Yaseen conducted an analysis of AI applications in EFL teaching, identifying collaboration networks and frequently cited studies[104]. While these studies highlight a growing interest in the use of DL in language instruction, few have specifically focused on reading instruction for EFL learners. Castañeda et al. emphasized the value of bibliometric techniques for trend identification in educational research, although their work did not target EFL contexts[105].

The limited number of bibliometric studies addressing DL in EFL reading instruction underscores the need for comprehensive mapping in this area. Bibliometric analysis can uncover trends, influential authors, and gaps in the literature, providing a foundation for future research and policy development[106]. Given the rapid growth of publications in this field, a bibliometric approach is essential for synthesizing existing knowledge and guiding effective practice.

3. Methodology

Using the bibliometric method, this paper examines the trends of research on deep learning (DL)–based reading instruction for EFL learners in 2015–2025. As a quantitative technique, bibliometric analysis helps researchers in visualizing patterns and trends as well as relationships across a literature body, which makes it particularly pertinent for identifying influential authors, significant themes, important topics, also new areas of investigation within this fast-paced area. For transparency and reproducibility, a PRISMA-like workflow involving four key stages (identification, screening, eligibility screening and inclusion) was adhered to.

The Dimensions AI database was chosen as the main source since it includes a wide range of peer-reviewed and open-access research outputs in education, linguistics, and computer science with good citation and metadata indexing. To minimize selection bias, additional searches were performed on Scopus and Web of Science (WoS) with the same time and word logic. Scopus and WoS both returned relevant records, but Dimensions showed better recall for DL and EFL-related documents, along with richer keyword and affiliation metadata. On this comparison basis, Dimensions was kept as the analytical backbone and Scopus and WoS played a complementary role to check coverage and control that no high-impact publication was overlooked.

The search tactic included the Boolean combinations of terms aimed at both deep learning architectures and reading pedagogy. Searches contained ‘deep learning’, ‘CNN’, ‘RNN’, ‘LSTM’ or ‘neural network’ combined with “reading”, “reading instruction”, “reading comprehension” or “reading model”, and 'EFL', 'ESL', or 'English as a foreign language'. Searches were limited to 2015 to 2025, English-language publications, and journal articles. Book chapters, conference proceedings, editorials and documents that did not specifically mention DL applied to reading and/or the EFL learning context were excluded. Even in cases where papers addressed DL across languages more broadly, inclusion was only made if there were clear reading outcomes (e.g., comprehension, decoding, fluency) included in the analysis.

The first Dimensions search returned 1178 records. Additional verification searches were conducted in Scopus and Web of Science, which identified 760 potentially relevant items; however, these overlapped substantially with Dimensions, and no uniquely high-impact articles were excluded.

After removing 277 duplicate records, 112 items were excluded during title and abstract screening for being irrelevant to DL, EFL, or reading instruction. A further 49 articles were excluded during full-text eligibility review because they were non-English, not peer-reviewed journal articles, or lacked a substantive focus on DL-based reading instruction. This process resulted in a final dataset of 322 articles that were subjected to bibliometric analysis. For data cleaning and aggregation, Microsoft Excel, Open Refine were used. Cleaning entailed normalization of DOIs, disambiguating author names (when present) using ORCID and normalizing institution names using GRID/ROR, harmonization of journal titles, and merging of keyword terms into variants (e.g., "reading comprehension" versus "reading-comprehension"). References with incomplete metadata — records lacking an essential element such as the DOI — were validated by means of a DOI backfilling, except in unresolved cases.

Analysis brought together both descriptive and network analysis methodologies. Descriptive statistics using Excel consisted of yearly publication volumes, key authors, institutions, countries and journals. VOSviewer (version 1.6. xx) was employed to build citation networks in four different aspects (i.e., co- authorship networks, co-citation networks, bibliography coupling networks and co-word network). To ensure analytical rigor and reproducibility, specific thresholds and parameters were applied. The types of analysis included co-authorship, co-citation, and co-occurrence analyses, with the units of analysis set as authors, documents, and all keywords. The full counting method was employed to assign equal weight to all items, ensuring that each author, keyword, or document contributed proportionally to the visualization regardless of publication frequency.

For the data inclusion, the thresholds were defined as follows: (1) a minimum of two documents per author, (2) five citations per author, (3) three occurrences per keyword, (4) three documents per organization, and (5) five documents per country.

4. Findings and Discussion

4.1. Publication Trends

The annual distribution of publications (see **Figure 1**) reveals a clear upward trend in research focused on deep learning – based reading instruction for EFL learners.

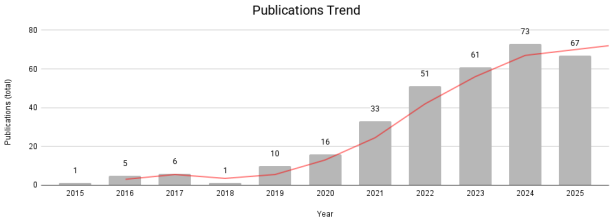

Figure 1. Publication Trends.

Starting with just 1 publication in 2015, the field saw growth through 2018, followed by a sharp increase beginning in 2019 with 10 publications, rising significantly to 73 publications in 2024 and slightly tapering to 67 in 2025. The steady increase reflects an expanding scholarly interest in the intersection of artificial intelligence, deep learning, and EFL pedagogy.

4.2. Research Categories

Most of the publications are categorized under Education (324 articles) and Curriculum and Pedagogy (246 articles) (see **Figure 2**), indicating that most of the research focuses on instructional strategies and teaching models.

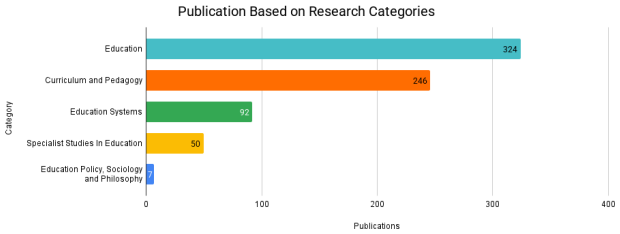

Figure 2. Publication Based on Research Categories.

Other categories include Education Systems (92), Specialist Studies in Education (50), and a smaller portion in Education Policy, Sociology, and Philosophy (7). This distribution demonstrates a strong emphasis on practical classroom applications rather than on policy or sociological theory.

4.3. Most Cited Sources

The most influential journals (see **Table 1**) include Sustainability (11 documents, 7823 citations), Computers and Education: Artificial Intelligence (5 documents, 635 citations), and Education and Information Technologies (10 documents, 295 citations).

Table 1. Most Cited Sources.

Source	Documents	Citations
Sustainability	11	738
Computers and Education Artificial Intelligence	5	635
Education and Information Technologies	10	295
International Journal of Emerging Technologies in Learning (IJET)	5	131
Education Sciences	7	86

These journals indicate that much of the high-impact research is published in interdisciplinary outlets combining education, technology, and sustainability studies.

4.4. Co-Authorship Analysis

This co-authorship network (see **Figure 3**) reveals several distinct research clusters. The most central authors include Ma, Jing, Zhang, Ying, and Sn, Daner, who relate to other active researchers such as Wan, Zhihong, Yang, Min, and Lin, Ming.

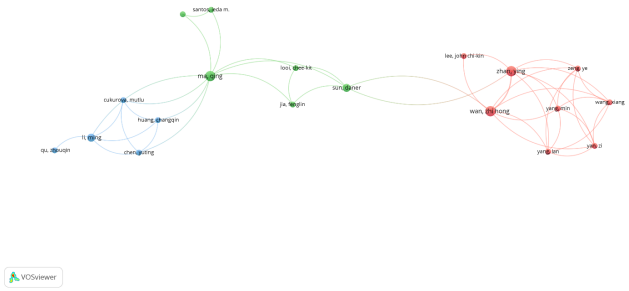

Figure 3. Co-authorship Network Analysis.

Three major collaboration groups can be observed, indicating both national and cross-institutional partnerships, with Zhang and Ying's group showing dense interconnection within a single cluster.

4.5. Keyword Co-Occurrences

Keyword co-occurrence mapping (see **Figure 4**) using VOS viewer shows high frequencies for terms such as "group" (136 occurrences), "class" (110), "assessment" (106), "feedback" (97), and "integration" (71).

This highlights that dominant themes in the field include classroom-based interventions, formative assessment strategies, and technology integration. Other frequent terms such as "motivation", "achievement", and "self-efficacy" suggest growing interest in learner-centered outcomes and affective variables in EFL contexts.

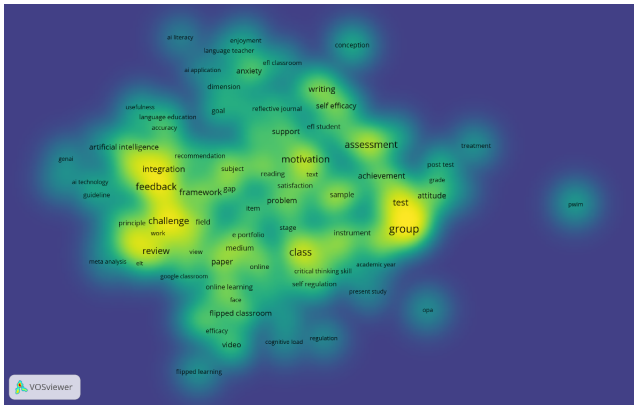

Figure 4. Co-occurrence Mapping.

4.6. International Research Collaboration

The bibliographic coupling map (see **Figure 5**) shows that China is the leading country in terms of research output and international collaboration, with significant connections to the United Kingdom, Vietnam, Australia, and the United States.

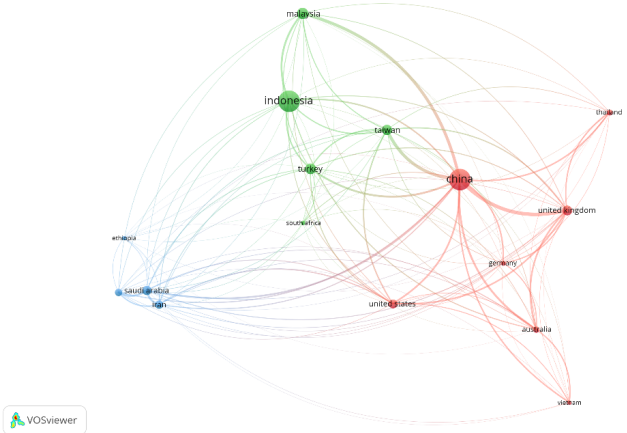

Figure 5. International Research Collaboration.

Indonesia and Malaysia also appear as key contributors in regional networks, collaborating frequently with Taiwan and Turkey. This spread underscores the relevance of DL and AI-based educational research across both developed and developing contexts.

4.7. Discussion

This bibliometric analysis reveals a significant and accelerating interest in the application of deep learning (DL) to enhance reading instruction within the English as a Foreign Language (EFL) context. The sharp rise in publications beginning in 2019, peaking in 2024 and continuing into 2025, underscores a global movement toward integrating artificial intelligence (AI) in education to meet demands for personalization, adaptability, and instructional automation [1,2,5]. The evolving trajectory of research shows DL's emergence as a transformative pedagogical strategy, with applications that span adaptive reading technologies, real-time feedback systems, and intelligent tutoring environments, all developed to address the complex linguistic, cognitive, and affective needs of EFL learners [6,29,38].

From the findings, there are for major thematic clusters that will be discussed. The first thematic culture identified through VOSviewer analysis centers on assessment and feedback, highlighting the educational community's growing focus on AI-driven diagnostic and formative evaluation tools. DL systems are being widely explored for their capacity to automate assessment, provide immediate feedback, and generate personalized learning pathways [37,99,107]. This reflects a pedagogical shift from traditional, summative evaluations to more dynamic, data-informed learning processes. For EFL learners, who often face challenges related to decoding unfamiliar vocabulary and managing reading anxiety, DL-powered systems can offer adaptive scaffolding, individualized pacing, and multimodal input that align closely with the Universal Design for Learning (UDL) principles [108,109]. Moreover, DL applications support predictive analytics that enable early intervention through the detection of reading difficulties based on learner behavior such as reading speed, click patterns, or eye-tracking data [11,26]. Such affordances operationalize the response to intervention (RTI) model more efficiently than traditional classroom-based monitoring.

The second major cluster revolves around learner motivation, engagement, and self-efficacy, indicating a notable paradigmatic shift from teacher-centered to learner-centered approaches in DL research. The co-occurrence of keywords such as "motivation", "feedback", "assessment", and "self-efficacy" reflects a growing interest in fostering learner autonomy, sustained engagement, and emotional regulation [49,76]. DL-enhanced reading tools, through adaptive gamification, emotional recognition, and interactive narrative elements, have been found to increase motivation and reading persistence among EFL learners. These learner-focused developments resonate with broader educational goals emphasizing differentiated instruction and constructive feedback, supporting students in becoming active participants in their learning process rather than passive recipients of information. The emphasis on motivation and feedback also connects to socio-affective outcomes, suggesting that DL systems may play a vital role not only in improving cognitive performance but also in cultivating learners' confidence and sense of agency in language learning contexts.

The third cluster, system design and implementation, represents the technological and interdisciplinary backbone of DL-based EFL research. This cluster encompasses studies on intelligent tutoring systems, architecture optimization, and adaptive content delivery. Journals such as *Sustainability*, *Computers and Education: Artificial Intelligence*, and *Education and Information Technologies* serve as leading publication venues, bridging education, technology, and sustainability research [103]. The prominence of these outlines illustrates that DL-EFL research has expanded beyond purely pedagogical questions to address systemic concerns such as scalability, equity, and ethical design [50,60]. Network analyses further reveal that China, the United Kingdom, Vietnam, and Australia are key contributors with high international co-authorship rates, indicative of robust digital infrastructure and policy alignment supporting AI-enhanced education [27,28]. In contrast, contributions from Indonesia and Malaysia remain modest in publication volume and citation impact, signaling a pressing need for investment in a localized research ecosystem [30]. In Indonesia, DL integration in EFL classrooms remains at a developmental stage, hindered by infrastructural limitations, insufficient computational resources, and limited professional training in AI pedagogy [53]. Additionally, current implementations often lack curricular alignment with emancipated curriculum, which emphasizes project-based and student-centered learning. Without proper contextual adaptation, DL applications risk being perceived as superficial technological add-ons rather than pedagogical innovations [98]. Yet, there is considerable potential for DL to support inclusive education, particularly for learners with reading difficulties or disabilities. Systems leveraging LSTM and NLP architectures can dynamically adapt texts

complexity, provide real-time comprehension support, and deliver multimodal scaffolds aligned with learners' cognitive profiles[14,15,110].

Ethical and transparency challenges remain a critical subtheme within the system design cluster. Many DL systems function as opaque "black boxes", limiting interpretability and potentially eroding user trust[10,13]. Moreover, biases arising from non-representative training data and concerns over data privacy require careful regulation and interdisciplinary oversight[32,33]. In low-technical inequalities, necessitating the development of interpretable and fair DL models that uphold transparency, accountability, and cultural relevance.

Moving forward, Indonesia and similar emerging research environments can capitalize on these insights by focusing on localized DL model development that embeds cultural narratives, vernacular materials, and multilingual resources. Universities and teacher education programs can play a pivotal role by integrating DL literacy into curricula and initiating collaborations with international partners for capacity building, research funding[52,54]. Strengthening research networks and ensuring alignment between AI innovations and national education priorities will be essential to foster sustainable, inclusive progress.

Overall, the global trajectory of DL-enhanced EFL reading instruction demonstrates both rapid expansion and rich thematic diversity. The clusters of assessment & feedback, learner motivation, and system design collectively illustrate the pedagogical, technological, and ethical challenges through targeted research and international collaboration will ensure that DL functions not merely as a technological enhancement but as a transformative pedagogical force promoting equitable, inclusive, and sustainable language education for all learners.

5. Conclusions

This bibliometric analysis provides a comprehensive overview of global research trends in deep learning-based reading instruction for English as a Foreign Language (EFL) learners from 2015 to 2025. The findings reveal a consistent increase in scholarly output, particularly in the past five years, indicating growing interest in the integration of artificial intelligence within language education. Most studies focus on classroom-level applications, such as adaptive learning, feedback mechanisms, and learner motivation, reflecting a shift toward student-centered and technology-enhanced instruction. Highly cited journals and international collaborations demonstrate the interdisciplinary and global nature of this field. However, the analysis also identifies a lack of representation from developing contexts, including Indonesia, where digital access and infrastructure remain uneven. Despite its emerging participation, Indonesia has yet to establish a strong research presence in high-impact outlets or form widespread international partnerships. This highlights a clear opportunity for Indonesian educators, researchers, and policymakers to contribute to the development of localized, inclusive, and culturally responsive DL-based reading instruction models. Future research should explore scalable frameworks tailored to Indonesia's diverse educational settings, invest in teacher training for AI integration, and examine how DL technologies can address equity and engagement in EFL learning. By responding to these gaps, Indonesia can not only enhance its national education system but also contribute meaningfully to the global conversation on AI-supported education.

Discussable implications are derived from these results. First, the need for culturally responsive and linguistically appropriate DL models that are grounded in the contexts of varied learner populations, especially from low-resource settings, by researchers cannot be overstated. Second, policy makers and institutions should invest in teacher professional development programs that not only develop teachers' technical competency but also link DL applications with existing reading theories based on schema theory, cognitive load theory and metacognitive strategy instruction. Third, international collaboration should be increased by the formation of joint projects and shared data infrastructures, as well as mutual publications, such that knowledge production becomes more inclusive and internationally representative.

Three main priority areas for future research are suggested, (1) scalable and explainable DL frameworks that can be integrated into everyday classroom use without being an over imposition on the teacher's work-load; (2) longitudinal studies investigating the long-term impact of DL-supported reading instruction on learner literacy development, equity and autonomy; and (3) targeted investigations as to how DL can facilitate learning among vulnerable groups including learners with reading disabilities in under-resourced or rural

schools.

By focusing on these priorities, educational research can shift from the activity of descriptive mapping to constructing actionable frameworks that directly shape classroom practice and national policy. For Indonesia and other rising contributors, this is both a challenge and an opportunity: to enhance participation in high-impact research networks while making sure innovations are open, equitable and well underpinned by the broader agendas of inclusive language education. In doing so, they can help propel local education systems forward and help guide the global conversation around AI-informed reading instruction.

Author Contributions

All authors contributed equally to the conception, design, data collection, analysis, and writing of this study. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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