

Digital Semantic Mapping Tools and Cognitive Reading Achievements among University EFL Learners: A Systematic Literature Review

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ABSTRACT: This systematic literature review examines the effectiveness of Digital Semantic Mapping Tools in enhancing cognitive reading achievement among university English as a Foreign Language (EFL) learners. Academic reading remains challenging for EFL students because of limited vocabulary, complex syntactic structures, and heavy cognitive demands, while research on digital concept-mapping interventions remains fragmented and rarely synthesized, particularly within the Indonesian higher education context. Following PRISMA 2020 guidelines, literature published between 2020 and 2025 was searched through Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, and Google Scholar, yielding five empirical studies that met the inclusion criteria. The reviewed studies employed diverse platforms, including Concept Mapping, Kit-Build Concept Map, Semantic Mapping, E-Mind Map, and Graphic Organizers. Findings show that these tools consistently improved reading comprehension, inferential reasoning, knowledge organization, information retention, and collaborative learning. Their effectiveness is explained by five interrelated cognitive mechanisms: schema activation, knowledge organization, inferential processing, metacognitive monitoring, and collaborative knowledge construction. The review proposes that Digital Semantic Mapping Tools function as an integrated cognitive learning ecosystem rather than as isolated instructional technologies, offering theoretical grounding for technology-based reading pedagogy and practical guidance for EFL instructors seeking to strengthen students' academic reading achievement in higher education.

Keywords: cognitive reading achievement, digital semantic mapping tools, EFL reading, higher education, systematic literature review.

ABSTRAK: Kajian literatur sistematis ini mengkaji efektivitas Digital Semantic Mapping Tools dalam meningkatkan capaian membaca kognitif mahasiswa pembelajar Bahasa Inggris sebagai Bahasa Asing (EFL) di perguruan tinggi. Membaca akademik masih menjadi tantangan bagi mahasiswa EFL karena keterbatasan kosakata, struktur sintaksis yang kompleks, dan beban kognitif yang berat, sementara penelitian mengenai intervensi pemetaan konsep digital masih terfragmentasi dan jarang disintesis, khususnya dalam konteks pendidikan tinggi di Indonesia. Dengan mengikuti pedoman PRISMA 2020, literatur yang diterbitkan antara tahun 2020 dan 2025 ditelusuri melalui Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, dan Google Scholar, dan menghasilkan lima studi empiris yang memenuhi kriteria inklusi. Studi-studi yang dikaji menggunakan berbagai platform, termasuk Concept Mapping, Kit-Build Concept Map, Semantic Mapping, E-Mind Map, dan Graphic Organizers. Temuan menunjukkan bahwa alat-alat tersebut secara konsisten meningkatkan pemahaman membaca, penalaran inferensial, pengorganisasian pengetahuan, retensi informasi, dan pembelajaran kolaboratif. Efektivitasnya dijelaskan oleh lima mekanisme kognitif yang saling berkaitan: aktivasi skema, pengorganisasian pengetahuan, pemrosesan inferensial, pemantauan metakognitif, dan konstruksi pengetahuan secara kolaboratif. Kajian ini mengusulkan

bahwa Digital Semantic Mapping Tools berfungsi sebagai ekosistem pembelajaran kognitif yang terintegrasi, bukan sekadar teknologi pembelajaran yang berdiri sendiri, sehingga menawarkan landasan teoretis bagi pedagogi membaca berbasis teknologi serta panduan praktis bagi pengajar EFL yang ingin memperkuat capaian membaca akademik mahasiswa di perguruan tinggi.

Kata kunci: *alat pemetaan semantik digital, capaian membaca kognitif, kajian literatur sistematis, membaca EFL, pendidikan tinggi.*

INTRODUCTION

Reading skills are one of the most fundamental academic competencies in higher education, as they serve as the primary means for students to acquire, evaluate, and construct knowledge from various academic sources. In a higher education setting, many learning activities depend on students' ability to understand academic articles, textbooks, research reports, and an increasingly diverse range of digital information sources. Consequently, academic success is determined not only by mastery of course material but also by students' ability to interpret information critically, integrate various concepts, and develop a deep understanding through reading. In the context of 21st-century learning, reading ability is also closely linked to higher-order thinking skills, such as analysis, synthesis, evaluation and problem-solving, which are key requirements for university graduates (Organisation for Economic Co-operation and Development [OECD], 2021; UNESCO, 2023). Consequently, the development of reading skills is no longer viewed merely as a linguistic skill, but as the foundation for the development of academic literacy, lifelong learning, and readiness to face the challenges of a knowledge-based society.

For students of English as a Foreign Language (EFL), these demands become more complex as they must comprehend academic texts in a language that is not their first language. Limited vocabulary, complex syntactic structures, and cultural differences often hinder the reading comprehension process, meaning that reading requires greater cognitive effort compared to native English speakers (Grabe & Stoller, 2020; Koda, 2023). Furthermore, the increasing number of digital learning resources requires EFL students not only to be able to read effectively, but also to select, organise and integrate information from various digital media. This situation highlights that improving the academic reading skills of EFL students is a key priority in higher education; consequently, learning strategies are needed that can support the process of meaning-making more effectively using digital technology.

Although reading proficiency is a key prerequisite for academic success at university, students of English as a Foreign Language (EFL) still face various challenges that hinder their comprehension of academic texts. Compared to general texts, academic reading is characterised by information density, the use of technical vocabulary, complex syntactic structures, and the need to analyse, synthesise and evaluate the information presented. These conditions mean that the reading process is not merely a linguistic activity but also involves a series of higher-order cognitive processes, such as the activation of prior knowledge, the formation of inferences, comprehension monitoring, and the integration of new

information into the reader's existing knowledge structure. For EFL students, this complexity is further heightened as they must process meaning in a second language whilst managing the limitations of their linguistic competence; consequently, the cognitive load experienced whilst reading is greater than that of first-language readers. Consequently, many students struggle to identify main ideas, draw implicit conclusions, understand relationships between concepts, and maintain comprehension when faced with lengthy, information-dense academic texts (Grabe & Stoller, 2020; Koda, 2023). Various recent studies also indicate that the challenges of academic reading are not solely related to limited vocabulary, but rather stem from a combination of linguistic, cognitive, and metacognitive factors. Students often struggle to understand academic terminology, make inferences, link information across chapters, and select reading strategies appropriate to their reading objectives. Furthermore, low levels of metacognitive awareness mean that students are less able to monitor their own understanding; consequently, they tend to continue reading without realising that misconceptions are arising or that meaning is being lost during the reading process. Research in the context of Indonesian higher education indicates that the main barriers faced by students include understanding academic vocabulary, interpreting complex sentences, developing inferences, and the sub-optimal use of reading strategies. In response to these challenges, students generally rely on rereading, note-taking, technological aids, and concept mapping techniques to improve their reading comprehension, although the effectiveness of these strategies still varies between individuals and learning contexts.

Advances in digital technology have brought about significant changes to reading instruction practices in higher education. The integration of technology no longer serves merely as a medium for delivering content but has evolved into a tool that supports knowledge construction, active learning and the development of higher-order thinking skills. Various digital learning platforms, such as learning management systems (LMS), interactive e-books, web-based reading applications, and artificial intelligence (AI)-assisted tools, provide students with the opportunity to access a wider range of learning resources, receive immediate feedback, and utilise various visual and multimedia features that can deepen their understanding of the text. In the context of learning English as a foreign language (EFL), digital transformation has also shifted the learning paradigm from a teacher-centred approach towards a more collaborative, adaptive and student-centred approach, thereby enabling the reading process to take place in a more interactive and meaningful way (Bond et al., 2024; UNESCO, 2023). In line with these developments, various studies indicate that digital technology can enhance the effectiveness of reading instruction by providing a learning environment that supports the visualisation of information, interactivity, personalisation, and self-regulated learning. Features such as digital annotations, hyperlinks, multimedia, interactive visualisation, and automated feedback help students connect new information with prior knowledge, thereby making the process of meaning-making more systematic. Furthermore, advances in educational technology are driving the use of artificial intelligence-based tools, learning analytics, and visual applications

capable of identifying students' learning needs and facilitating the development of more effective reading strategies. However, the effectiveness of digital technology is determined not only by the sophistication of the platform used, but also by the appropriateness of the underlying learning strategies. Consequently, researchers' focus has begun to shift from merely evaluating the use of technology towards examining how technology can support the cognitive processes involved in reading comprehension. One approach that has garnered widespread attention in recent years is the use of Digital Semantic Mapping Tools—digital tools that enable students to visualise relationships between concepts, organise information systematically, and construct deeper representations of knowledge during the reading process (Mayer, 2021; Zawacki-Richter & Qayyum, 2021; Crompton & Burke, 2023). This approach is regarded as having great potential to reduce cognitive load whilst enhancing the quality of academic reading comprehension among EFL students, making it a key focus in recent research.

Digital semantic mapping tools are an evolution of conventional semantic mapping strategies, utilising digital technology to visualise relationships between concepts, organise information, and facilitate the process of meaning construction whilst reading. Unlike concept maps created manually, the digital versions offer a range of interactive features, such as real-time editing, online collaboration, the integration of images, videos and hyperlinks, as well as cloud-based storage, which enables students to build and revise their representations of knowledge more flexibly. Various platforms, such as MindMeister, CmapTools, XMind, MindMup, Miro, and Lucidchart, have been widely utilised in language learning to help students identify key ideas, connect important concepts, organise information hierarchically, and develop a more structured understanding of academic texts. Visualising these interconnections between concepts not only makes it easier for students to understand the content of a text but also helps them organise complex information into a more systematic and memorable knowledge structure. In the context of reading instruction for EFL learners, Digital Semantic Mapping Tools are regarded as a strategy capable of simultaneously integrating linguistic and cognitive processes. When students read academic texts, they not only identify the meaning of words or sentences, but also establish logical connections between ideas, activate prior knowledge, and link new information to existing schemata. This process becomes more effective through digital visualisation, which allows students to see the interconnections between concepts explicitly, reduces the fragmentation of information, and facilitates the synthesis of various ideas within the text. In addition to supporting individual learning, various digital platforms also provide collaborative features that enable students to build semantic maps together, discuss relationships between concepts, and provide immediate feedback. These characteristics make Digital Semantic Mapping Tools not merely a medium for visualising information, but also a learning environment that supports knowledge construction, social interaction, and the development of critical thinking skills. Consequently, in recent years this approach has been increasingly adopted in language learning research as it is considered capable of enhancing reading comprehension, information retention, engagement with

learning, and the ability to integrate information from various digital sources (Novak & Cañas, 2008; Ifenthaler, 2022; Crompton & Burke, 2023; Mayer, 2021; Al-Jarf, 2023).

Although the use of Digital Semantic Mapping Tools has attracted increasing attention in EFL reading instruction, the existing body of research remains fragmented in several respects. Most empirical studies have evaluated the effectiveness of individual digital mapping platforms within specific classroom contexts, employing different intervention durations, instructional models, participant characteristics, and assessment measures. Consequently, the literature provides considerable evidence that digital semantic mapping can improve reading performance, yet offers limited understanding of the cognitive mechanisms through which these improvements occur across diverse university EFL contexts. Furthermore, previous studies have largely examined learning outcomes independently rather than synthesizing how technological, pedagogical, and learner-related factors interact to influence the effectiveness of Digital Semantic Mapping Tools.

Existing reviews have also tended to summarize empirical findings descriptively, focusing primarily on whether concept mapping improves reading achievement. Much less attention has been devoted to integrating complementary learning theories into a coherent explanatory framework capable of explaining why, how, and under what instructional conditions Digital Semantic Mapping Tools facilitate cognitive reading achievement. As a result, the theoretical understanding of digital semantic mapping remains dispersed across individual perspectives such as Schema Theory, Meaningful Learning Theory, Constructivism, Cognitive Theory of Multimedia Learning, and Cognitive Load Theory, without a unified conceptual model that explains their combined contribution to technology-enhanced academic reading.

To address these gaps, this study conducts a Systematic Literature Review (SLR) following the PRISMA 2020 framework to synthesize empirical evidence concerning the use of Digital Semantic Mapping Tools for improving cognitive reading achievement among university EFL learners. Beyond identifying publication trends, intervention characteristics, digital platforms, theoretical foundations, and learning outcomes, this review critically compares findings across studies to identify recurring patterns, inconsistencies, contextual differences, and factors that influence instructional effectiveness. The review therefore moves beyond descriptive evidence synthesis by developing an explanatory interpretation of how Digital Semantic Mapping Tools support higher-order academic reading.

METHODS

This study employed a Systematic Literature Review (SLR) to synthesize empirical evidence concerning the use of Digital Semantic Mapping Tools in enhancing cognitive reading achievement among university-level English as a Foreign Language (EFL) learners. The review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

2020 guidelines to ensure transparency and completeness in reporting the identification, screening, eligibility assessment, and inclusion of studies. PRISMA 2020 was used as a reporting framework rather than as a statistical analysis method. The literature search was conducted from 2021 to 2026 through Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, and Google Scholar.

Inclusion and Exclusion Criteria

Selected articles were required to meet the following inclusion criteria: 1) Published between 2020 and 2025; 2) Empirical research articles that have undergone a peer-review process; 3) Address the use of Digital Semantic Mapping Tools, semantic mapping, or concept mapping in English reading instruction; 4) Involve university students as participants; 5) Report learning outcomes related to reading abilities, such as reading comprehension, reading achievement, critical reading, inferencing, vocabulary acquisition, or other cognitive indicators; 6) Available in either English or Indonesian with full-text access. Meanwhile, articles were excluded if they were proceedings, editorials, books, theses, dissertations, conceptual articles, review articles, or did not provide adequate methodological information and research findings. Articles focusing on primary and secondary education levels were also excluded from the review.

Article Selection Process and Data Extraction

The study selection process followed the PRISMA 2020 (Figure 1) reporting framework and consisted of four main stages: identification, screening, eligibility, and inclusion. During the identification stage, records retrieved from the selected databases were compiled, and duplicates were removed. During screening, titles and abstracts were assessed against the predefined eligibility criteria. Potentially relevant reports were subsequently retrieved for full-text assessment. During the eligibility stage, each full-text report was assessed against all inclusion and exclusion criteria. Reasons for exclusion at the full-text stage were recorded and categorized. Finally, studies satisfying all eligibility criteria were included in the qualitative synthesis.

Information from each article was extracted using a systematically designed data extraction sheet. The collected data included: 1) Article identity (authors, year, country, and publication source); 2) Participant characteristics; 3) Research design; 4) Types of Digital Semantic Mapping Tools used; 5) Intervention duration; 6) Theoretical foundations; 7) Data collection instruments; 8) Cognitive reading achievement indicators measured; 9) Main research findings. Data extraction was performed consistently to facilitate cross-study comparisons and to identify patterns, similarities, and differences across research outcomes.

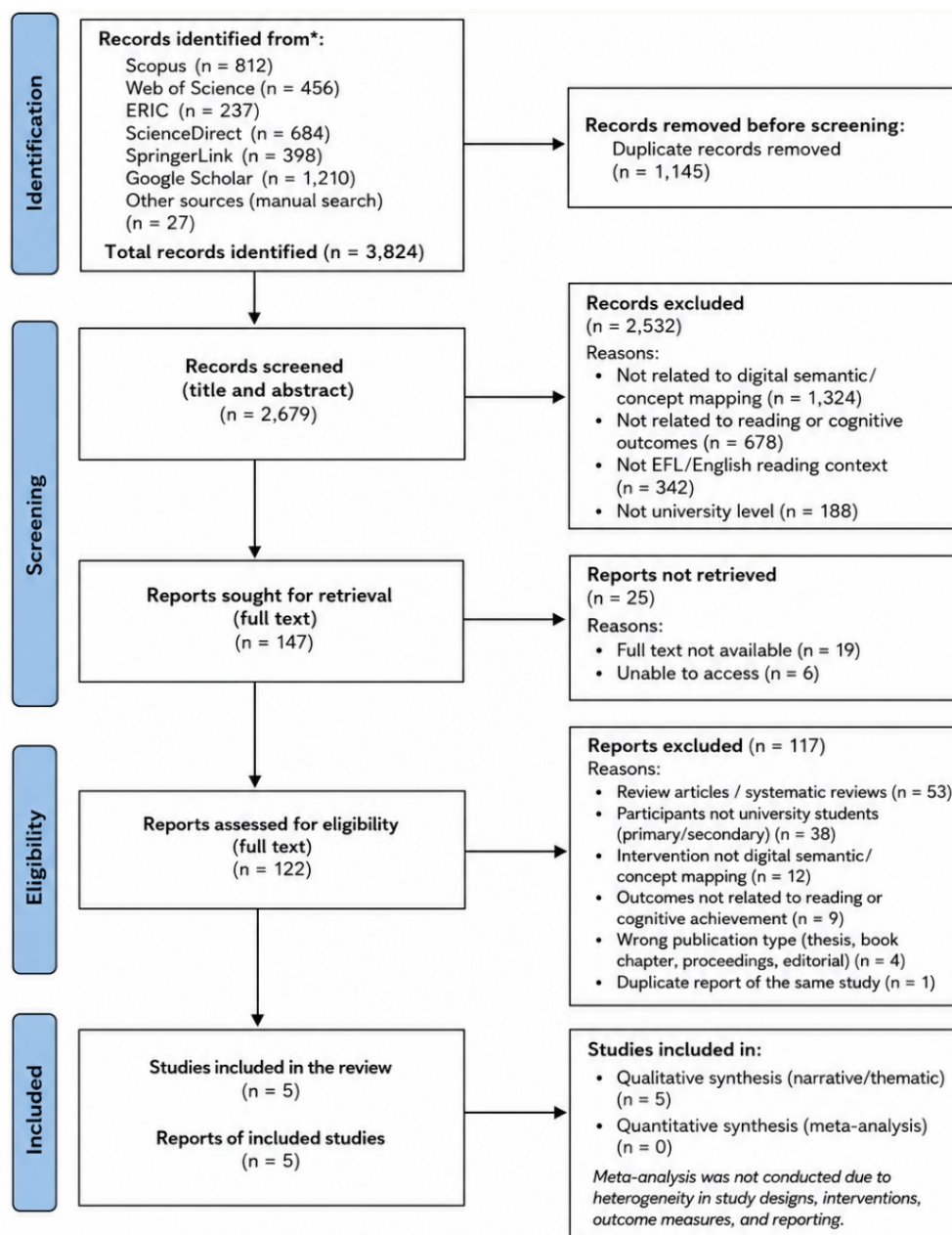


Figure 1. PRISMA 2020

Data Analysis

Analysis was conducted using a thematic synthesis approach, grouping research findings based on major themes emerging from the literature. These themes include: (1) characteristics of the Digital Semantic Mapping Tools employed, (2) effects on reading comprehension and cognitive reading achievement, (3) effects on vocabulary mastery and inferencing abilities, (4) impacts on students' cognitive and metacognitive engagement, (5) factors influencing the effectiveness of implementation, and (6) challenges and opportunities for application in reading instruction at Indonesian universities. The synthesis results are then presented descriptively and narratively to indicate research trends, identify knowledge gaps, and formulate theoretical and practical

implications for the development of technology-based digital reading instruction within the Indonesian higher education context.

FINDINGS AND DISCUSSION

Characteristics of the Synthesized Studies

The synthesis stage resulted in five articles that met the inclusion criteria and passed the *full-text eligibility* process. These articles were systematically analyzed to identify research characteristics, types of interventions, digital platforms used, research designs, and reported reading achievement indicators. Although the number of eligible articles remains limited, all of them are highly relevant to the focus of this study on the use of *Digital Semantic Mapping Tools* to enhance *cognitive reading achievement* among *English as a Foreign Language* (EFL) learners.

Table 1. Distribution of Articles by Year of Publication

Year	Number of Articles	Percentage
2021	2	40.0%
2022	0	0.0%
2023	3	60.0%
2024	0	0.0%
2025	0	0.0%
Total	5	100%

The publication distribution shows that most studies were published in 2023. This finding indicates a growing interest in the use of digital concept mapping as a reading instruction strategy following the expansion of digital learning in the post-pandemic era. Although the number of publications is still relatively small, this trend suggests that the integration of visual technology in reading instruction is gaining increasing attention in the field of *English Language Teaching*.

Table 2. Distribution of Articles by Country

Country	Number of Articles
Malaysia (SLR)	1
Japan	1
Morocco	1
Indonesia	1
Jordan	1
Total	5

The distribution across countries indicates that research on *Digital Semantic Mapping Tools* has been conducted in diverse educational contexts. Japan and Indonesia represent Asian contexts with a focus on technology-based learning, while Morocco and Jordan reflect the implementation of visual strategies in EFL contexts in the Middle East and North Africa. The inclusion of one *systematic*

literature review article from Malaysia provides a synthesized perspective that reinforces empirical findings from experimental studies.

Despite originating from different countries, most studies share similar characteristics, namely the use of visual strategies to help students organize information, connect key concepts in texts, and improve comprehension of academic reading materials. This suggests that the need to support meaning construction through concept visualization is a cross-contextual issue.

Table 3. Distribution by Research Design

Research Design	Number	Percentage
Experimental	2	40.0%
Quasi-experimental	1	20.0%
Systematic Literature Review	1	20.0%
Survey	1	20.0%
Total	5	100%

As shown in Table 3, experimental design is the most used approach. The dominance of experimental studies indicates that researchers primarily aim to directly test the effectiveness of *Digital Semantic Mapping Tools* by comparing experimental and control groups or by using *pretest–posttest* designs. This approach allows for the measurement of changes in reading ability after students receive interventions based on digital concept mapping.

On the other hand, quasi-experimental studies provide additional evidence of the effectiveness of *semantic mapping* strategies in more natural classroom settings. Meanwhile, survey studies enrich the synthesis by offering insights into educators' perceptions of using *graphic organizers* in reading instruction. The inclusion of a *systematic literature review* article is also important, as it confirms that previous research findings generally support the use of *concept mapping* as a reading instruction strategy.

Methodologically, the variation in research designs demonstrates that evidence regarding the effectiveness of *Digital Semantic Mapping Tools* does not rely on a single research approach. However, the dominance of experimental studies suggests that the field is still largely focused on testing intervention effectiveness. Longitudinal studies, *mixed methods*, and designs based on *learning analytics* remain very limited, presenting opportunities for future research.

The analysis of research characteristics also reveals similarities in the dependent variables used. Nearly all studies identify *reading comprehension* as the primary indicator of learning success. However, some studies extend the measurement by including inferential reading ability, information retention, knowledge construction, and the quality of collaborative interaction. These findings indicate that *Digital Semantic Mapping Tools* are not only viewed as strategies to improve literal comprehension but also as approaches that support higher-order cognitive processes in reading.

In terms of technological implementation, there is a diversity of platforms used, including *Concept Mapping*, *Semantic Mapping*, *Kit-Build Concept Map*, *E-Mind Map*, and *Graphic Organizer*. Although these platforms differ in form and

features, they share a common characteristic: visualizing relationships among concepts so that students can build more structured knowledge representations. This shared characteristic forms the basis for the thematic analysis in the following section, which examines how these various digital platforms contribute to enhancing *cognitive reading achievement*. Overall, the characteristics of the synthesized studies indicate that the field of *Digital Semantic Mapping Tools* is still in its early stages of development but has shown relatively consistent findings. Most studies report positive impacts on reading ability, despite variations in research design, digital platforms, and implementation contexts. This condition provides a foundation for further exploration of the characteristics of each digital platform and the mechanisms through which concept mapping contributes to improving EFL students' reading abilities.

Digital Semantic Mapping Tools Used in Reading Instruction

The analysis of articles that met the inclusion criteria indicates that research on the use of Digital Semantic Mapping Tools in EFL students' reading instruction employs a variety of platforms and visual approaches. Although all studies share a common objective—supporting students in organizing information and constructing relationships among concepts during reading—each study implements different technologies depending on the instructional context and intervention goals.

Table 4. Types of Digital Semantic Mapping Tools Used

Platform	Main Characteristics	Supporting Studies
Concept Mapping	Visualization of relationships among concepts through nodes and links	Ta & Razali (2023)
Kit-Build Concept Map	Collaborative digital concept mapping using a <i>kit-building</i> mechanism	Pinandito et al. (2021)
Semantic Mapping	Mapping relationships among words, concepts, and main ideas	Mouchrif et al. (2023)
E-Mind Map	Digital mind mapping integrated with online learning	Hardiyanti et al. (2021)
Graphic Organizer	Visual representation of information structure to support reading strategies	Fraihat & Bani Abdelrahman (2020)

Table 4 shows that each study adopts a different visual approach; however, all share a common feature: the graphical representation of relationships among concepts. The main differences lie in the level of interactivity, collaboration mechanisms, and available digital features. Concept Mapping and Semantic Mapping focus more on hierarchical organization and semantic relationships, whereas E-Mind Map offers greater visual flexibility through dynamically expandable idea branches. Meanwhile, Kit-Build Concept Map is specifically designed to support collaborative learning by providing predefined concept components that students reorganize, allowing the knowledge construction process to be observed more systematically.

Table 5. Characteristics of Digital Semantic Mapping Tools Implementation

Aspect	Synthesis Findings
Main objective	Organizing concepts and improving reading comprehension
Visual format	Node–link structures, concept branches, semantic maps, graphic organizers
Learning mode	Individual and collaborative
Media	Computers, web-based applications, online platforms
Main activities	Identifying main ideas, linking concepts, organizing information hierarchically, reflecting on reading content
Learning outcomes	Reading comprehension, inferential ability, information retention, and knowledge construction

The synthesis results indicate that all platforms are used to help students build visual representations of reading content. Learning activities generally begin with reading academic texts, followed by identifying key concepts, grouping important information, establishing relationships among concepts, and reflecting on the mapping results. This process encourages students not only to understand information linearly but also to construct logical connections among ideas, leading to deeper comprehension of the text.

However, variations exist in how each platform is implemented. In studies using Kit-Build Concept Map, students work collaboratively to reconstruct provided concepts, making peer discussion a crucial part of the learning process. In contrast, studies employing Semantic Mapping emphasize the activation of prior knowledge through the development of semantic networks before and during reading. Meanwhile, E-Mind Map is integrated into the Think–Pair–Share learning model, making concept visualization part of collaborative and reflective activities. Overall, the five studies demonstrate a consistent pattern: the effectiveness of digital platforms is not solely determined by the type of application used, but by how the platform facilitates students' cognitive processes. Platforms that allow students to connect concepts, discuss relationships among ideas, and revise their knowledge representations tend to produce better outcomes than those relying on passive visualization. This finding suggests that the primary function of *Digital Semantic Mapping Tools* is not merely to generate visual diagrams, but to support active knowledge construction during reading.

Furthermore, the synthesis reveals that no single platform dominates research in this field. The diversity of applications reflects the ongoing opportunity to develop more adaptive concept mapping technologies tailored to the needs of EFL students in higher education. This condition also indicates that current research focuses more on the effectiveness of concept visualization strategies rather than on the superiority of specific software. Therefore, future studies should compare the effectiveness of various digital platforms using standardized

experimental designs to provide stronger empirical evidence regarding which tools are most effective in enhancing EFL students' *cognitive reading achievement*.

The Impact of Digital Semantic Mapping Tools on *Cognitive Reading Achievement*

The analysis of articles that met the inclusion criteria indicates that the use of *Digital Semantic Mapping Tools* contributes positively to various aspects of EFL students' *cognitive reading achievement*. Although each study employed different digital platforms and intervention designs, all empirical studies reported improvements in one or more indicators of reading ability after students participated in concept mapping-based learning. These impacts are not only reflected in enhanced *reading comprehension*, but also in students' ability to make inferences, organize information, construct knowledge representations, and increase engagement during the reading process.

Table 6. The Impact of Digital Semantic Mapping Tools on Cognitive Reading Achievement Indicators

Indicator	Supporting Articles	Synthesis of Findings
Reading comprehension	Pinandito et al. (2021); Hardiyanti et al. (2021); Ta & Razali (2023)	Concept mapping-based interventions improve reading comprehension through more systematic information organization.
Inferential reading	Mouchrif et al. (2023)	Semantic mapping has a stronger effect on inferential reading than on literal comprehension.
Knowledge organization	Pinandito et al. (2021); Ta & Razali (2023)	Students find it easier to connect main ideas with supporting concepts during reading.
Knowledge retention	Ta & Razali (2023)	Concept visualization helps retain information in long-term memory.
Collaborative learning	Pinandito et al. (2021); Hardiyanti et al. (2021)	Digital platforms encourage discussion and collaborative knowledge construction.

As shown in Table 6, the most consistently reported indicator is the improvement in reading comprehension. Experimental studies using *Kit-Build Concept Map* and *E-Mind Map* demonstrate that students are better able to identify main ideas, understand relationships between concepts, and organize information more systematically compared to conventional learning methods. These findings suggest that concept visualization helps reduce the complexity of academic texts, enabling students to construct a clearer understanding of the content.

In addition to improving general reading comprehension, several studies also indicate that *Digital Semantic Mapping Tools* contribute to the development of inferential reading skills. In the study by Mouchrif et al. (2023), students who

learned using *semantic mapping* showed more significant improvement in drawing implicit conclusions than in understanding explicit information. This finding suggests that semantic mapping not only helps students recognize textual content but also facilitates information integration, the development of logical relationships among ideas, and the formation of inferences during reading.

Table 7. Impact on Students' Cognitive Processes

Cognitive Aspect	Evidence from Synthesis
Activation of prior knowledge	Students connect new concepts with prior knowledge or experiences.
Information organization	Information is structured more systematically and becomes easier to understand.
Concept integration	Relationships among ideas become clearer through visual representation.
Comprehension monitoring	Students can more easily identify parts of the text they do not understand.
Information retention	Visual representations help retain information for a longer period.

Table 8 shows that the primary benefits of *Digital Semantic Mapping Tools* extend beyond improved reading scores to include cognitive processes that support learning. All studies indicate that concept visualization encourages students to activate prior knowledge, categorize information based on conceptual relationships, and construct more structured mental representations. As a result, students no longer read texts linearly but instead build networks of meaning that facilitate comprehension and information retention.

Another notable finding is the improvement in the quality of interaction during the learning process. In studies implementing *Kit-Build Concept Map* and *E-Mind Map*, concept mapping activities were conducted collaboratively, allowing students to discuss relationships among concepts, provide peer feedback, and revise their understanding based on group discussions. These activities strengthen knowledge construction processes and enhance student engagement in reading tasks.

Table 8. Summary of the Impact of Digital Semantic Mapping Tools

Dimension	Key Findings	Implications
Cognitive	Improves comprehension, inference, and information retention.	Helps students understand complex academic texts.
Metacognitive	Supports monitoring of reading comprehension through concept visualization.	Encourages the use of more strategic reading approaches.
Collaborative	Enhances interaction and academic discussion.	Strengthens social knowledge construction.

Pedagogical	Supports active, student-centered reading instruction.	Relevant for higher education reading contexts.
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The synthesis of the analyzed articles indicates that *Digital Semantic Mapping Tools* have strong potential to enhance multiple dimensions of *cognitive reading achievement*. Despite differences in the platforms used, all interventions share a common characteristic: visualizing relationships among concepts, which enables students to develop a deeper understanding of academic texts. These findings suggest that the effectiveness of *Digital Semantic Mapping Tools* is not solely determined by the sophistication of the technology, but by their ability to facilitate knowledge organization, information integration, and meaning construction during reading. However, this synthesis also reveals that empirical evidence is still dominated by studies with relatively short intervention durations and limited sample sizes. Variations in research contexts, types of digital platforms, and participant characteristics make it difficult to generalize the findings broadly. Therefore, further research is needed using longitudinal designs, larger sample sizes, and direct comparisons among different *Digital Semantic Mapping Tools* platforms to gain a more comprehensive understanding of their effectiveness in improving EFL students' *cognitive reading achievement*.

Theoretical Foundations and Factors Influencing the Effectiveness of Digital Semantic Mapping Tools

The analysis of the synthesized articles indicates that the effectiveness of *Digital Semantic Mapping Tools* is not solely influenced using technology, but also by the theoretical foundations that support their implementation. Various studies employ cognitive learning theories to explain how concept visualization helps students construct understanding of academic texts. Although each study adopts different perspectives, there is a consistent tendency that the processes of prior knowledge activation, information organization, knowledge construction, and collaborative interaction serve as the main mechanisms explaining improvements in *cognitive reading achievement*.

Table 9. Theoretical Foundations Used in the Studies

Theoretical Foundation	Supporting Articles	Role in Reading Learning
Schema Theory	Ta & Razali (2023); Mouchrif et al. (2023)	Activates prior knowledge and connects new information with existing knowledge structures of the reader.
Constructivism	Pinandito et al. (2021); Fraihat & Bani Abdelrahman (2020)	Students construct understanding through active and reflective learning activities.
Collaborative Learning	Pinandito et al. (2021); Hardiyanti et al. (2021)	Encourages discussion, negotiation of meaning, and joint concept construction.

Meaningful Learning	Ta & Razali (2023)	Facilitates the integration of new concepts with previously understood concepts, making learning more meaningful.
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Table 9 shows that Schema Theory is the most dominant conceptual foundation in the synthesized studies. This theory explains that reading comprehension occurs when readers can connect new information with their existing knowledge structures (*schemas*). In the context of using *Digital Semantic Mapping Tools*, this process is facilitated through the visualization of relationships among concepts, enabling students to more easily identify main ideas, connect supporting information, and construct mental representations of the reading content.

In addition to *Schema Theory*, several studies adopt the perspective of Constructivism, which views learning as an active process of knowledge construction. Through the creation of digital concept maps, students do not merely receive information passively but actively organize, connect, and revise concepts based on their reading. This activity allows for gradual meaning construction, leading to deeper comprehension of texts.

Studies implementing Kit-Build Concept Map and E-Mind Map also demonstrate that Collaborative Learning plays a significant role in enhancing the quality of reading instruction. Group-based concept mapping provides opportunities for students to discuss conceptual relationships, give peer feedback, and correct misunderstandings through the negotiation of meaning. Thus, concept visualization not only supports individual cognitive processes but also strengthens learning through social interaction.

Table 10. Factors Influencing the Effectiveness of Digital Semantic Mapping Tools

Factor	Synthesis Findings	Implications
Digital platform characteristics	Platforms with visual and collaborative features support better knowledge organization.	Platform selection should align with learning objectives.
Implementation strategies	Integration with active learning models, such as Think–Pair–Share or collaborative learning, enhances effectiveness.	Technology should be combined with appropriate pedagogical strategies.
Learner characteristics	Language proficiency and digital literacy influence successful platform use.	Students require orientation and guidance before using digital platforms.
Text type	Complex academic texts benefit more from concept visualization.	Concept mapping is effective for texts with complex interrelationships among ideas.

Collaborative interaction	Discussion and shared reflection strengthen knowledge construction.	Collaborative activities should be integrated into digital reading instruction.
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As shown in Table 10, the effectiveness of *Digital Semantic Mapping Tools* is influenced by a combination of technological, pedagogical, and learner-related factors. Digital platforms that provide visualization, editing, and collaboration features enable students to develop understanding more systematically compared to platforms that function merely as tools for drawing concept maps. However, technology does not operate independently of instructional strategies. The synthesis results indicate that greater benefits are achieved when concept mapping is integrated with active learning models that encourage students to engage in discussion, reflect on their reading, and revise their constructed knowledge representations.

Another factor influencing effectiveness is learner characteristics. Students with higher levels of English proficiency and digital literacy tend to utilize digital platform features more effectively for organizing information. Conversely, students who are less familiar with concept mapping applications require orientation and guidance to ensure that the use of technology does not increase their cognitive burden. Additionally, the type of text used also determines the success of implementation. Academic texts with complex conceptual structures are more suitable for integration with *Digital Semantic Mapping Tools*, as concept visualization helps students understand the relationships between main ideas and supporting information.

The synthesis results indicate that the successful use of *Digital Semantic Mapping Tools* does not depend on a single factor. Their effectiveness is the result of the interaction between theoretical foundations that support the learning process, applied pedagogical design, characteristics of digital platforms, and students' readiness to utilize technology. Therefore, the implementation of *Digital Semantic Mapping Tools* in higher education should be designed as part of a comprehensive reading instruction strategy, rather than merely as the use of software for creating concept maps.

Discussion

Why Do Digital Concept Mapping Tools Improve Cognitive Reading Achievement?

The present systematic review sought to synthesize empirical evidence regarding the effectiveness of Digital Concept Mapping Tools in enhancing cognitive reading achievement among university English as a Foreign Language (EFL) learners. The synthesis demonstrates a consistent pattern across the reviewed studies: digital concept mapping improves reading achievement not simply because it introduces technology into the classroom, but because it fundamentally transforms how learners process, organize, and construct meaning from academic texts. Rather than functioning as passive visual aids, digital concept mapping environments encourage learners to actively organize information,

identify conceptual relationships, activate prior knowledge, and continuously reorganize their understanding while reading. Consequently, reading evolves from a linear decoding activity into a dynamic process of cognitive knowledge construction.

This finding provides an important explanation for why nearly all empirical studies included in this review reported positive learning outcomes despite employing different digital platforms, instructional models, and research designs. The common denominator among these interventions is not the technological sophistication of the software itself but the cognitive processes facilitated by visual knowledge organization. Whether learners used Concept Mapping, Semantic Mapping, Kit-Build Concept Maps, E-Mind Maps, or Graphic Organizers, each intervention required students to externalize their thinking through visual representations that explicitly illustrated relationships among concepts. Such visualization appears to support deeper comprehension because learners are encouraged to interpret, reorganize, and integrate information rather than merely identify isolated ideas.

The effectiveness of this process can first be understood through Schema Theory (Anderson, 1984; Rumelhart, 1980), which proposes that reading comprehension occurs when new information is successfully integrated into readers' existing knowledge structures. According to this perspective, comprehension depends not only on linguistic competence but also on the activation of appropriate prior knowledge during reading. The reviewed studies consistently suggest that Digital Concept Mapping Tools facilitate schema activation by enabling learners to visually connect unfamiliar concepts with previously acquired knowledge. Instead of processing each paragraph independently, students construct interconnected conceptual networks that represent the overall meaning of the text. This visual organization reduces conceptual fragmentation and enables readers to integrate multiple ideas into coherent cognitive structures.

The present synthesis extends this theoretical explanation by demonstrating that digital visualization strengthens schema activation more effectively than conventional note-taking or linear summarization. Traditional reading strategies often require learners to mentally organize numerous disconnected pieces of information, placing considerable demands on working memory. In contrast, digital concept maps externalize these relationships, allowing learners to allocate greater cognitive resources to comprehension rather than information management. This interpretation is consistent with the findings of Ta and Razali (2023), who concluded that concept mapping enhances reading comprehension by facilitating conceptual organization and supporting long-term knowledge retention. Likewise, Pinandito et al. (2021) reported that collaborative digital concept mapping significantly improved university EFL learners' understanding of academic texts because learners actively reconstructed conceptual relationships throughout the reading process.

The findings are equally consistent with Ausubel's Meaningful Learning Theory (Ausubel, 1968), which argues that meaningful learning occurs when new

knowledge is consciously integrated with existing conceptual frameworks. From this perspective, Digital Concept Mapping Tools function not merely as organizational devices but as cognitive mediators that support meaningful learning. Students do not simply record information from texts; instead, they reorganize concepts into personally meaningful knowledge structures. This process promotes deeper comprehension because learners continuously evaluate conceptual relationships, revise misconceptions, and establish hierarchical connections among ideas.

The synthesized evidence also supports Novak and Cañas' Concept Mapping Theory (Novak & Cañas, 2008), which emphasizes that concept maps represent external manifestations of learners' cognitive structures. The reviewed studies indicate that digital environments extend the pedagogical potential of conventional concept mapping by enabling real-time revision, collaborative construction, multimedia integration, and interactive visualization. Consequently, Digital Concept Mapping Tools facilitate a continuous cycle of knowledge construction in which learners repeatedly refine their conceptual representations as new information emerges during reading.

Another theoretical perspective explaining the effectiveness of Digital Concept Mapping Tools is Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2021). According to CTML, meaningful learning occurs when learners actively integrate verbal and visual information through separate but interconnected cognitive channels. Academic reading traditionally relies almost exclusively on verbal processing. Digital concept maps introduce a complementary visual channel that enables learners to distribute cognitive processing across verbal and pictorial representations. By simultaneously processing textual information and visual conceptual structures, learners develop richer mental models of academic content. This mechanism explains why several studies reported improvements not only in literal comprehension but also in inferential reasoning, knowledge integration, and long-term retention.

Similarly, the findings may also be interpreted through Dual Coding Theory (Paivio, 1986), which suggests that information encoded simultaneously through verbal and visual systems is more likely to be retained and retrieved successfully. Digital Concept Mapping Tools transform abstract textual information into interconnected visual representations, thereby strengthening cognitive encoding processes. This dual representation enables learners to recall conceptual relationships more efficiently and to reconstruct textual meaning more accurately during subsequent learning activities.

Beyond facilitating information encoding, Digital Concept Mapping Tools also appear to reduce the cognitive burden associated with processing complex academic texts. This finding aligns with Cognitive Load Theory (Sweller, 2011), which argues that effective instructional design should minimize unnecessary cognitive processing while maximizing learners' capacity for meaningful learning. Academic texts frequently contain dense terminology, lengthy explanations, and multiple interconnected concepts that can overwhelm learners' working memory. The reviewed studies suggest that digital concept mapping alleviates this problem

by organizing information into visually coherent conceptual structures, thereby reducing extraneous cognitive load and allowing learners to focus on higher-order comprehension processes.

Importantly, the present review indicates that technology itself is not the primary determinant of learning effectiveness. Rather, Digital Concept Mapping Tools become effective because they support pedagogical processes that encourage active engagement with academic texts. This observation explains why different digital platforms produced relatively similar outcomes despite variations in interface design and technological features. The effectiveness of concept mapping therefore appears to depend more on the quality of instructional implementation than on software characteristics alone. This interpretation is consistent with recent educational technology research, which argues that digital learning environments improve learning outcomes only when technology is integrated with appropriate pedagogical strategies rather than functioning as an independent instructional solution.

Taken together, the findings of this review suggest that Digital Concept Mapping Tools should be conceptualized not merely as instructional technologies but as cognitive scaffolding systems that mediate knowledge construction during academic reading. This interpretation extends previous research by emphasizing that improvements in cognitive reading achievement emerge through the interaction between visual representation, schema activation, meaningful learning, multimedia processing, and reduced cognitive load. Consequently, the contribution of Digital Concept Mapping Tools lies not simply in making reading more attractive or interactive, but in restructuring the cognitive architecture through which university EFL learners construct meaning from academic texts.

The discussion presented above provides the first theoretical explanation for the effectiveness of Digital Concept Mapping Tools. However, understanding why these tools improve reading achievement requires further examination of the underlying cognitive mechanisms operating during reading. Therefore, the following section proposes a more comprehensive explanation of the cognitive processes through which digital concept mapping facilitates higher-order reading achievement, ultimately leading to the development of a conceptual framework derived from the synthesis findings.

The Cognitive Mechanisms Underlying Digital Concept Mapping in Academic Reading

Although the reviewed studies consistently demonstrate positive effects of Digital Concept Mapping Tools on reading achievement, the findings suggest that these improvements do not occur as a direct consequence of technology use. Instead, the synthesis indicates that digital concept mapping facilitates a sequence of interconnected cognitive processes that collectively enhance learners' comprehension of academic texts. The effectiveness of these tools therefore appears to be mediated by several cognitive mechanisms, including schema activation, knowledge organization, inferential processing, metacognitive monitoring, and collaborative knowledge construction. Understanding these

mechanisms is essential because they explain not only whether Digital Concept Mapping Tools improve reading performance, but also how such improvements are cognitively achieved.

The first mechanism identified in this review is schema activation. Across the synthesized studies, learners were consistently encouraged to identify key concepts before organizing them into conceptual networks. This activity activated existing knowledge structures that enabled learners to interpret new information more efficiently. Rather than processing isolated sentences independently, learners continuously related unfamiliar concepts to previously acquired knowledge, thereby facilitating deeper comprehension of academic texts. This finding reinforces Schema Theory, which emphasizes that successful reading depends on readers' ability to activate relevant prior knowledge and integrate new information into existing cognitive frameworks. The visual organization provided by Digital Concept Mapping Tools appears to strengthen this activation process because conceptual relationships become explicit and cognitively accessible throughout reading.

The second mechanism concerns knowledge organization, which emerged as one of the most consistent characteristics across all reviewed interventions. Academic texts frequently contain complex conceptual relationships that challenge learners' working memory and often lead to fragmented understanding. The reviewed studies indicate that Digital Concept Mapping Tools reduce this complexity by transforming linear textual information into hierarchical conceptual structures. Such visual representations enable learners to recognize relationships among ideas, distinguish major concepts from supporting information, and construct coherent mental models of academic content. Consequently, reading shifts from simple information acquisition toward structured knowledge construction.

This mechanism is strongly supported by Meaningful Learning Theory, which argues that meaningful understanding develops when concepts are organized hierarchically and integrated into existing cognitive structures. The synthesis suggests that Digital Concept Mapping Tools operationalize this principle by allowing learners to externalize their conceptual understanding and continuously revise it during reading. Unlike traditional notetaking, which often records information sequentially, concept mapping requires learners to evaluate conceptual relationships before constructing visual knowledge structures. This active organizational process appears to strengthen both comprehension and long-term retention.

Another important mechanism emerging from the synthesis is inferential processing. Several reviewed studies indicate that learners using Digital Concept Mapping Tools demonstrated greater improvement in inferential comprehension than in literal comprehension. This finding suggests that digital mapping primarily supports higher-order thinking rather than basic information recall. Inferential reading requires learners to identify implicit relationships, synthesize information across different parts of a text, and generate logical conclusions beyond explicitly stated ideas. By visualizing conceptual connections, Digital Concept Mapping Tools

facilitate these inferential processes because learners can more easily identify patterns and relationships that remain hidden in linear text.

This interpretation aligns closely with Cognitive Theory of Multimedia Learning (CTML), which proposes that meaningful learning depends on learners' ability to integrate verbal and visual information into coherent mental representations. During academic reading, learners simultaneously process textual information and conceptual diagrams, allowing them to construct integrated cognitive models rather than isolated verbal representations. Consequently, Digital Concept Mapping Tools extend learners' cognitive processing beyond decoding written language toward conceptual reasoning and analytical thinking.

The synthesis further indicates that Digital Concept Mapping Tools support metacognitive monitoring, an aspect that has received relatively limited attention in previous research. While constructing digital concept maps, learners continuously evaluate whether conceptual relationships accurately represent textual meaning. When inconsistencies emerge, learners revise, reorganize, or expand their conceptual networks until meaningful relationships become apparent. This recursive process encourages learners to monitor their own understanding rather than passively accepting information from the text. Therefore, concept mapping functions simultaneously as a learning strategy and a metacognitive regulation strategy.

The importance of metacognitive monitoring can also be interpreted through Self-Regulated Learning Theory, which argues that effective learners actively plan, monitor, and evaluate their own learning processes. Digital Concept Mapping Tools provide external representations of learners' thinking, making cognitive processes visible and therefore easier to evaluate. This visualization enables learners to identify conceptual gaps, monitor comprehension difficulties, and modify their learning strategies accordingly. Such findings suggest that concept mapping contributes not only to cognitive development but also to learners' self-regulation during academic reading.

A further mechanism identified in this review is collaborative knowledge construction. Studies employing collaborative digital concept mapping consistently reported improvements in learner engagement, discussion quality, and conceptual understanding. Rather than individually constructing knowledge, learners negotiated conceptual relationships through peer interaction, justified their interpretations, and refined conceptual structures based on collaborative feedback. This social dimension appears to strengthen comprehension because learners are exposed to multiple perspectives that challenge and expand their existing cognitive frameworks.

The collaborative mechanism is consistent with Social Constructivist Theory, particularly Vygotsky's notion that higher cognitive functions develop through socially mediated interaction. Digital Concept Mapping Tools create environments where learners collectively construct conceptual representations instead of merely sharing answers. Consequently, learning becomes an interactive process of negotiating meaning, revising misconceptions, and co-constructing

academic knowledge. This collaborative dimension distinguishes digital concept mapping from conventional graphic organizers that are frequently used only as individual learning activities.

Taken together, these findings suggest that the effectiveness of Digital Concept Mapping Tools is best understood as the interaction of multiple cognitive mechanisms rather than the influence of a single instructional technique. Based on the synthesized evidence, this review proposes that Digital Concept Mapping operates through a multi-stage cognitive pathway consisting of schema activation, knowledge organization, inferential processing, metacognitive monitoring, and collaborative knowledge construction. These mechanisms collectively transform academic reading into an active process of constructing meaning rather than merely extracting information from texts.

This conceptual interpretation extends previous research by integrating multiple theoretical perspectives into a single explanatory framework. Earlier studies generally interpreted concept mapping through individual theories such as Schema Theory or Meaningful Learning Theory. In contrast, the present review suggests that no single theory sufficiently explains the complexity of Digital Concept Mapping Tools. Instead, their effectiveness emerges from the interaction of complementary cognitive and socio-constructivist mechanisms that operate simultaneously throughout the reading process.

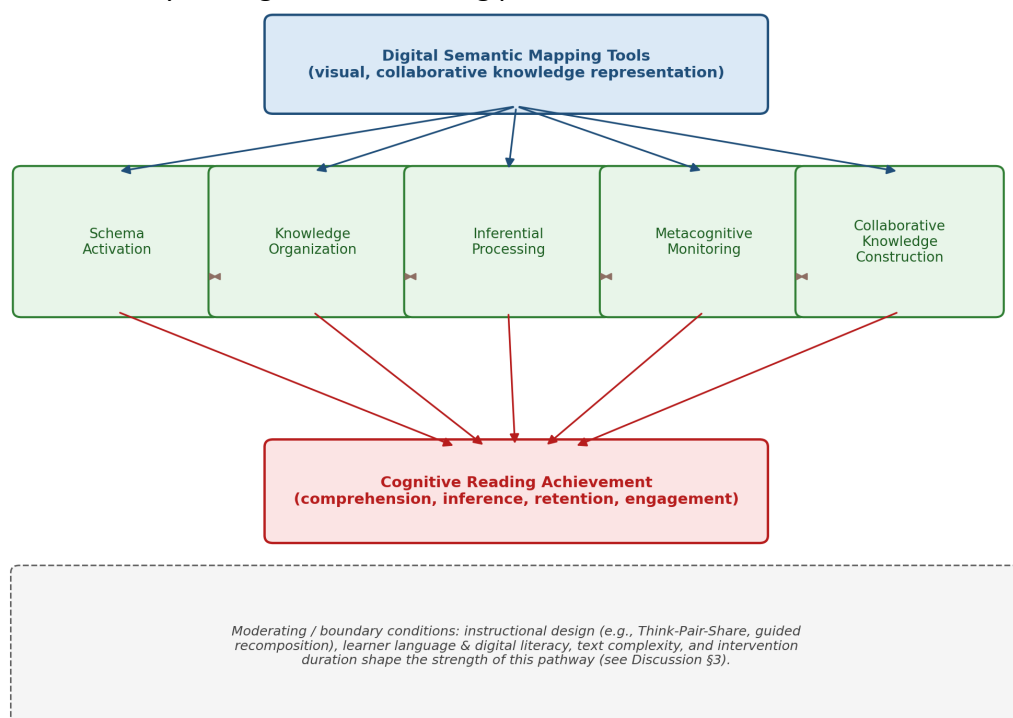


Figure 2. Integrated Cognitive Learning Ecosystem Model of Digital Semantic Mapping Tools and Cognitive Reading Achievement

Accordingly, this review proposes that Digital Concept Mapping should be conceptualized as an integrated cognitive learning ecosystem, in which visual representation, prior knowledge activation, conceptual organization,

metacognitive regulation, and collaborative interaction function as mutually reinforcing processes that collectively enhance cognitive reading achievement among university EFL learners. This proposition represents an important theoretical contribution because it shifts the perspective from viewing concept mapping as a simple instructional technique toward understanding it as a multidimensional cognitive learning framework capable of supporting higher-order academic literacy.

Contradictions, Boundary Conditions, and Differences Across Platforms

Although the synthesis presented above emphasizes convergence across studies, a critical reading of the evidence also reveals meaningful contradictions and boundary conditions that qualify the overall positive picture. First, the effect of Digital Semantic Mapping Tools is not uniform across comprehension sub-skills: Mouchrif et al. (2023) found a stronger effect on inferential comprehension than on literal comprehension, suggesting that these tools may be most beneficial for higher-order reasoning rather than basic fact retrieval, and that reviews reporting only an aggregate “improvement in reading comprehension” risk obscuring this differential pattern. Second, the reviewed studies differ in whether the reported benefit can be attributed to the mapping tool itself or to a co-occurring pedagogical structure: Hardiyanti et al.’s findings are embedded within a Think-Pair-Share instructional protocol, and Pinandito et al.’s (2021) advantage for Kit-Build Concept Map over open-ended mapping reflects the effect of a guided recomposition mechanism rather than digital visualization in general. This confound means the reviewed literature supports the claim that digital mapping combined with structured pedagogy improves reading achievement more strongly than it supports the claim that digital mapping tools are effective as a stand-alone intervention.

Third, platform architecture appears to moderate outcomes in ways the current evidence base cannot fully disentangle. Collaborative, structured tools (Kit-Build Concept Map) and individually oriented, free-form tools (Concept Mapping, E-Mind Map, Graphic Organizers) were not compared directly within a single study, so claims that collaboration or structure drives the advantage remain inferential rather than demonstrated. Fourth, none of the five included studies reports a null or negative finding, which is itself noteworthy: a literature in which every included study reports a positive effect is consistent either with genuinely robust effectiveness or with publication bias favoring positive results, small-sample designs prone to inflated effect estimates, or a file-drawer problem in which null findings on digital mapping tools go unpublished or unindexed by Google Scholar. This review cannot adjudicate between these explanations with the available evidence and treats the absence of contrary findings as an open question rather than as confirmatory evidence of universal effectiveness (see Limitations).

Taken together, these contradictions and boundary conditions indicate that Digital Semantic Mapping Tools are conditionally rather than universally effective: their benefit appears strongest for inferential and collaborative

outcomes, is entangled with the instructional design in which the tool is embedded and has so far been evidenced only under conditions (short interventions, small samples, single institutions) that limit generalization. The conceptual model proposed in this review (Figure 2) therefore represents the mechanisms through which these tools can operate under favorable conditions, rather than a guarantee of effectiveness under all conditions.

CONCLUSION

This systematic literature review synthesized empirical evidence concerning the effectiveness of Digital Concept Mapping Tools in enhancing cognitive reading achievement among university English as a Foreign Language (EFL) learners. The review demonstrates that Digital Concept Mapping Tools, including Concept Mapping, Semantic Mapping, Kit-Build Concept Maps, E-Mind Maps, and Digital Graphic Organizers, consistently improve reading comprehension by enabling learners to organize knowledge, establish conceptual relationships, and actively construct meaning from academic texts. Across the reviewed studies, the positive effects of these tools extended beyond literal comprehension to encompass inferential reasoning, knowledge organization, information retention, collaborative learning, and higher-order cognitive engagement. These findings indicate that Digital Concept Mapping Tools should be understood not merely as instructional technologies but as pedagogical strategies that enhance learners' cognitive processing during academic reading.

More importantly, the present review provides a theoretical explanation for why Digital Concept Mapping Tools improve reading achievement. The synthesis suggests that their effectiveness is mediated through five interrelated cognitive mechanisms: schema activation, knowledge organization, inferential processing, metacognitive monitoring, and collaborative knowledge construction. Rather than directly influencing learning outcomes, digital mapping environments facilitate meaningful learning by externalizing conceptual relationships, reducing unnecessary cognitive processing, and supporting learners in constructing coherent mental representations of academic texts. This interpretation extends previous research by integrating insights from Schema Theory, Meaningful Learning Theory, Cognitive Theory of Multimedia Learning, Dual Coding Theory, Cognitive Load Theory, and Social Constructivism into a unified explanatory perspective.

One of the principal contributions of this review is the development of an integrated conceptual explanation describing how Digital Concept Mapping Tools support cognitive reading achievement. Based on the synthesized evidence, this review proposes that digital concept mapping functions as a cognitive learning ecosystem in which visual representation, prior knowledge activation, conceptual organization, reflective monitoring, and collaborative interaction operate as mutually reinforcing processes. This conceptual proposition expands existing literature by shifting the focus from evaluating the effectiveness of individual digital mapping platforms toward understanding the cognitive mechanisms that explain why such tools consistently improve academic reading performance.

Consequently, the review contributes not only to the empirical literature on technology-enhanced language learning but also to the theoretical understanding of cognitive reading development in university EFL contexts.

From a pedagogical perspective, the findings suggest that integrating Digital Concept Mapping Tools into university EFL reading instruction can promote more active, reflective, and learner-centered reading practices. However, the review also indicates that successful implementation depends on thoughtful instructional design rather than technology alone. Learning activities that combine concept visualization with collaborative discussion, guided reflection, and metacognitive regulation appear to maximize the educational benefits of digital mapping. Therefore, instructors should incorporate concept mapping as part of comprehensive reading pedagogy instead of treating it as an isolated technological application.

Despite these contributions, several limitations should be acknowledged. The body of empirical research specifically examining Digital Concept Mapping Tools in university EFL contexts remains relatively limited, and many studies employed small samples, short intervention periods, and diverse outcome measures, reducing opportunities for direct comparison. Moreover, the reviewed literature investigated a wide variety of digital mapping platforms, making it difficult to determine the relative effectiveness of individual technologies. Future research should therefore employ longitudinal and multi-institutional designs, standardized assessment instruments, and larger participant populations to strengthen the evidence base. Comparative studies investigating different digital mapping platforms, as well as the integration of artificial intelligence-assisted concept mapping, adaptive learning analytics, and intelligent feedback systems, would further advance understanding of technology-supported academic reading.

In conclusion, this review demonstrates that the educational value of Digital Concept Mapping Tools lies not primarily in their digital features but in their capacity to transform reading into an active process of knowledge construction. By supporting learners in organizing information, activating prior knowledge, engaging in reflective thinking, and collaboratively constructing meaning, Digital Concept Mapping Tools provide a promising pedagogical framework for fostering cognitive reading achievement in higher education. As digital learning environments continue to evolve, concept mapping is likely to become an increasingly important component of evidence-based EFL reading instruction, particularly when integrated with emerging intelligent educational technologies and cognitively informed pedagogical practices.

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