JOURNAL OF
APPLIED LANGUAGE AND DISCOURSE STUDIES (JALDS)

The Impact of Computer-Assisted Concept Mapping on Iraqi EFL Students' Metacognitive Awareness and Reading Comprehension

Mohammd Qasim Sabti Al-Amiri, Hamid Varmazyari*, Ali Mohammad Mohammadi

Department of English Language and Literature, Faculty of Letters and Languages, Arak University, Arak, Iran

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Citation: Al-Amiri, M. Q. S., Varmazyari, H., & Mohammadi, A. M. (2026). The impact of computer-assisted concept mapping on Iraqi EFL students' metacognitive awareness and reading comprehension. *Journal of Applied Language and Discourse Studies*, *1*(1), 28–43.

https://doi.org/10.66224/jalds.1.1.28

KEYWORDS

computer-assisted concept mapping, EFL learners, metacognitive awareness, reading comprehension, Iraqi higher education

ABSTRACT

Computer-assisted concept mapping has emerged as a promising digital strategy for enhancing reading instruction, yet its effectiveness in EFL contexts remains underexplored. This study investigated the impact of computer-assisted concept mapping on the development of Iraqi EFL university students' metacognitive awareness and reading comprehension. Sixty first-year learners at an intermediate proficiency level, determined by the Oxford Placement Test, were assigned to experimental (n=30) and control (n=30) groups from two existing intact class sections. Metacognitive awareness was assessed using an adapted Metacognitive Reading Questionnaire (MRQ) based on Phakiti (2003), and reading comprehension was assessed through a researcher-developed test based on IELTS reading task formats. The experimental group received reading instruction integrated with computer-assisted concept mapping activities over seven weeks, while the control group followed traditional instruction. A two-way mixed-design analysis of variance (ANOVA) revealed significant Group × Time interaction effects for both dependent variables, with large effect sizes (partial η^2 = .51, 95% CI [.32, .66] for metacognition; partial η^2 = .49, 95% CI [.30, .64] for comprehension). Results indicate that students exposed to computer-assisted concept mapping demonstrated significantly greater gains compared to those receiving traditional instruction. These findings indicate that computer-assisted concept mapping may support deeper engagement with text structure and foster strategic, self-regulated reading. The study contributes to the limited body of research on strategy-based digital interventions in Iraqi EFL contexts.

* Corresponding author.
E-mail address: h-varmazyari@araku.ac.ir
DOI: https://doi.org/10.66224/jalds.1.1.28
Received: 13 May 2026; Received in revised form: 20 June 2026; Accepted: 21 June 2026
Article type: Original Article

Publisher: Arak University

1. Introduction

Reading comprehension is a fundamental skill for academic success, particularly for learners of English as a Foreign Language (EFL) (Macaro, 2003). In EFL contexts, where exposure to authentic language input is often limited, the ability to effectively process written texts becomes crucial for both language acquisition and content learning. Without strong reading comprehension, students struggle to access academic materials, engage with disciplinary content, or participate fully in university education. However, despite years of formal English instruction, many Iraqi EFL university students continue to experience persistent difficulties in reading comprehension, especially when engaging with academic texts (see, e.g., Hezam et al., 2022; Salman, 2025).

Reading comprehension difficulties and limited metacognitive awareness have been well documented among EFL learners in various contexts (Baker & Brown, 1984; Phakiti, 2003; Nguyen et al., 2014). However, limited research has examined these issues specifically in the Iraqi context. This study therefore investigates whether computer-assisted concept mapping can address these challenges among Iraqi EFL university students.

Metacognition—the awareness and regulation of one's own thinking processes—enables learners to plan before reading, monitor understanding during reading, and evaluate comprehension after reading (Baker & Brown, 1984; Flavell, 1979). Skilled readers are distinguished not only by their linguistic knowledge but also by their ability to strategically regulate cognitive processes (Soto et al., 2019). In contrast, less skilled readers often fail to recognize when comprehension breaks down or lack strategies to repair understanding.

Despite the acknowledged importance of metacognition, reading instruction in many Iraqi universities remains predominantly lecture-based and teacher-centered. Research by Mahmood (2025) found that while Kurdish EFL lecturers viewed problem-based and collaborative learning as most effective, lecture-based instruction predominated in their classrooms, indicating a persistent gap between beliefs and practice. Additional challenges include limited resources, insufficient training, and inadequate integration of technology (Mahmood, 2025). Consequently, students are often unprepared to engage actively with texts or regulate their reading strategies independently (Al-Obaydi et al., 2024; Salman, 2025). This instructional gap represents a missed opportunity to develop the strategic reading skills that underlie academic achievement across disciplines (see also Mahmood, 2025, for similar findings in Kurdish EFL contexts).

Concept mapping, developed by Novak at Cornell University (Novak & Cañas, 2008), has emerged as a promising tool for enhancing both comprehension and metacognition. Concept maps are graphical tools for organizing knowledge, consisting of concepts enclosed in nodes and relationships indicated by labeled linking lines. Unlike unstructured graphic organizers, concept maps follow specific design principles: concept clarity, propositional quality, hierarchical organization, and cross-links that connect different branches of knowledge. When applied to reading, concept mapping helps students visualize text structure and monitor understanding (Schwendimann, 2014).

With technological advancement, computer-assisted concept mapping—creating and revising concept maps using digital tools—has gained attention in EFL education (Liu et al., 2010). Computer-assisted concept mapping offers advantages over paper-and-pencil methods, including ease of editing, scalability, and enhanced visualization (Aşıksoy, 2019). These affordances may be particularly beneficial for developing metacognitive awareness, as they allow students to repeatedly revise maps and reflect on their understanding. The revision history

feature, for example, enables learners to track how their conceptual understanding has changed over time, providing tangible evidence of learning progress.

This study examines the impact of computer-assisted concept mapping on Iraqi EFL students' metacognitive awareness and reading comprehension. While previous research has explored the role of metacognitive strategies on Iraqi EFL learners' reading comprehension, the use of visual mapping strategies on higher-order thinking skills, and the impact of various other cognitive tools on reading comprehension, relatively little research has specifically investigated the effect of computer-assisted concept mapping on both metacognitive awareness and reading comprehension within the Iraqi EFL university setting. The present study, thus, employed a quasi-experimental design to examine these two interrelated variables concurrently. By combining a digital concept mapping intervention with the simultaneous assessment of cognitive and metacognitive outcomes, this research contributes to the growing body of literature on technology-mediated strategy instruction and self-regulated reading in the Iraqi EFL context. To address the gaps identified above, this study is guided by two research questions:

RQ1. What is the effect of computer-assisted concept mapping on Iraqi EFL students' metacognitive awareness?

RQ2. What is the effect of computer-assisted concept mapping on Iraqi EFL students' reading comprehension?

2. Literature Review

2.1. Reading Comprehension in EFL Contexts

Reading comprehension is an active process of meaning construction from written text, wherein readers coordinate multiple sources of information to form coherent mental representations (Elleman & Oslund, 2019). Successful comprehension requires efficient lower-level processes (word recognition, syntactic parsing) and higher-level processes that enable readers to connect ideas within and beyond the text (Rice et al., 2024). Lower-level processes operate automatically in skilled readers, freeing cognitive resources for the inferential and integrative work that characterizes deep understanding.

Several theoretical models have informed contemporary understandings of reading comprehension. The Simple View of Reading (Gough & Tunmer, 1986) emphasizes the interaction of decoding and linguistic comprehension, whereas the Component Model of Reading (Aaron et al., 2008) highlights cognitive, psychological, and ecological influences. The Construction–Integration Model (Kintsch, 1998) further emphasizes the role of inferential processing in constructing coherent mental representations. Together, these frameworks suggest that successful comprehension requires active meaning construction, making them relevant to concept-mapping approaches.

These frameworks collectively support the use of concept mapping. By requiring learners to identify key concepts and represent relationships among them, concept mapping promotes active meaning construction, supports inferential processing, and helps readers develop deeper representations of textual information (Kintsch, 1998; Novak & Cañas, 2008).

In EFL contexts, learners often encounter challenges related to vocabulary knowledge, syntactic complexity, background knowledge, and ineffective strategy use (Al-Jarrah & Ismail, 2018; Evenddy et al., 2021). Among these factors, ineffective strategy use is particularly

important because many learners lack the metacognitive skills required to monitor comprehension and repair misunderstandings during reading (Phakiti, 2003). Computer-assisted concept mapping may help address this limitation by promoting active engagement with text structure.

Ineffective use of reading strategies is closely associated with limited metacognitive awareness—the ability to plan, monitor, and evaluate one's own comprehension processes. Skilled readers are distinguished not only by their linguistic knowledge but also by their strategic regulation of cognitive processes (Soto et al., 2019). As the following section will demonstrate, metacognitive awareness enables learners to plan before reading, monitor understanding during reading, and evaluate comprehension after reading. The failure to deploy effective strategies, documented above, thus reflects a broader deficit in metacognitive regulation—a deficit that computer-assisted concept mapping may help remediate.

2.2. Metacognitive Awareness in Reading

Metacognition consists of two components: metacognitive knowledge and metacognitive regulation (Flavell, 1979). The two components mutually support each other in a dynamic, cyclical relationship. Rich metacognitive knowledge enhances the ability to differentiate regulatory responses, while effective regulation expands knowledge by producing insights grounded in authentic reading experiences (Cromley, 2023). This closed-loop control system is the engine of self-regulated learning, aligning processing with task demands, minimizing drift into superficial decoding, and enabling timely repairs when coherence breaks down (Winne & Hadwin, 1998).

Metacognitive knowledge includes declarative (knowing what), procedural (knowing how), and conditional knowledge (knowing when and why) (Soto et al., 2019). Declarative knowledge refers to understanding what strategies are available; procedural knowledge involves knowing how to execute them; conditional knowledge enables learners to select appropriate strategies for specific reading situations. Metacognitive regulation involves three interlocking phases: planning, monitoring, and evaluating (Bozorgian & Shamsi, 2025). In reading, planning occurs before reading (setting purposes, previewing structure); monitoring occurs during reading (tracking comprehension, adjusting strategies); evaluation occurs after reading (assessing outcomes, reflecting on effectiveness) (Bozorgian et al., 2022).

Research from neighboring EFL contexts has consistently demonstrated the importance of metacognitive awareness for reading comprehension. In Saudi Arabia, Alkhaleefah (2023) assessed metacognitive awareness among 260 university EFL learners and found that problem-solving strategies (e.g., adjusting reading speed, re-reading difficult passages) were reported most frequently, while global strategies (e.g., previewing text characteristics, setting a purpose for reading) were used least often. Importantly, proficiency level significantly predicted strategy use: high-proficiency learners reported more frequent use of global and problem-solving strategies than their lower-proficiency peers. This finding underscores the need for explicit metacognitive instruction, particularly for less proficient readers.

Similarly, Althewini (2025) examined Saudi EFL teachers' beliefs and practices regarding metacognitive reading strategies, revealing a gap between theoretical awareness and classroom implementation due to institutional constraints, rigid curricula, and lack of professional training. A similar situation appears to exist in Iraqi higher education, where traditional, teacher-centered instruction remains prevalent.

In Iran, Mortazavizadeh et al. (2024) compared explicit versus implicit metacognitive strategy instruction with 119 university EFL learners and found that the explicit instruction group significantly outperformed both the implicit and control groups in reading comprehension. Their finding that explicit, structured training in metacognitive strategies yields the strongest comprehension gains directly supports the design of the present study's intervention. Similarly, Tavakoli and Koosha (2016) found that explicit metacognitive strategy instruction significantly improved Iranian university EFL students' reading comprehension and self-efficacy, providing further evidence for the effectiveness of metacognitive approaches in EFL reading instruction.

Taken together, these recent studies from contexts closely resembling Iraq—in terms of learner population, instructional challenges, and EFL status—provide a strong empirical foundation for the present investigation. They demonstrate both the need for metacognitive strategy instruction in the region and the effectiveness of explicit, structured interventions for improving reading comprehension.

Metacognitive strategy instruction has proven effective in enhancing reading comprehension across EFL contexts (Bozorgian & Aalaam, 2018). Momdjian and Chidiac (2024) found that teaching metacognitive strategies to Arab underachieving ESL learners led to significant improvements in reading comprehension, with students demonstrating greater text engagement, inferencing ability, and metacognitive awareness. These findings align with the rationale for the present study's computer-assisted concept mapping intervention, which similarly seeks to scaffold metacognitive processes through structured pre-reading, while-reading, and post-reading activities.

2.3. Concept Mapping and Computer-Assisted Concept Mapping

Concept mapping, rooted in Ausubel's assimilation theory, externalizes knowledge structures through nodes representing concepts and labeled links representing relationships (Novak & Cañas, 2007). Concept maps are tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes, and relationships between concepts or propositions, indicated by a connecting line between two concepts (Novak, 2012). Key principles include concept clarity, propositional quality, hierarchical organization, and cross-links (Novak & Cañas, 2008). Concept clarity requires that nodes label regularities or ideas using concise noun phrases. Propositional quality demands that every link carry a linking phrase that forms a meaningful proposition when read from concept A to concept B. Hierarchical organization structures the map from most inclusive concepts at the top to more specific concepts below. Cross-links connect concepts in different branches, revealing integrative relationships that require higher-order synthesis.

When applied to reading, concept mapping serves multiple functions: activating prior knowledge before reading, extracting concepts during reading, and evaluating understanding after reading (Novak, 2010, 2012). Research has demonstrated its effectiveness for comprehension across educational levels (Chang et al., 2002; Tajeddin & Tabatabaei, 2016).

2.4. Empirical Studies

A growing body of research has examined the effects of concept mapping on reading comprehension in EFL contexts. When synthesized, this literature reveals consistent patterns of positive effects, but also important contradictions, methodological limitations, and unresolved questions that the present study addresses.

Across multiple contexts, studies have reported that concept mapping improves reading comprehension. Liu et al. (2010) found that computer-assisted concept mapping significantly enhanced comprehension among 192 Taiwanese college students, with particularly strong gains for lower-proficiency learners. Khajavi and Ketabi (2012) reported similar comprehension gains among Iranian EFL students, noting additional improvements in self-efficacy. Trang (2017) and Riahi and Pourdana (2017) extended these findings to Vietnamese and Iranian contexts, respectively, with both studies confirming that concept mapping outperforms traditional instruction. More recently, Namaziandost et al. (2023) found that both mind mapping and concept mapping improved comprehension and motivation among Iranian EFL students, with no significant difference between the two mapping techniques.

Taken together, these studies consistently support the conclusion that concept mapping enhances reading comprehension across diverse EFL settings. However, several critical gaps and contradictions remain unresolved.

While some studies suggest that computer-assisted (computer-based) concept mapping offers advantages over paper-based methods, the evidence is mixed. Almelhi (2017) found that Saudi EFL students using computer-based concept mapping showed significant advantages over those using conventional paper-based mapping, attributing the difference to digital affordances such as easy editing and revision tracking. Similarly, Liu et al. (2010) and Aşıksoy (2019) reported that computer-assisted mapping facilitated iterative refinement of understanding, reducing the cognitive cost of revision. In contrast, other studies have found no significant difference between digital and paper-based mapping when instructional protocols are held constant (Schroeder et al., 2018; Tajeddin & Tabatabaei, 2016). This contradiction suggests that the benefits of computer-assisted mapping may depend on instructional design factors—such as scaffolding, training duration, and integration with reading tasks—rather than the technology alone. The present study addresses this gap by implementing a structured seven-week protocol that explicitly scaffolds metacognitive processes, allowing the effects of computer-assisted mapping to be assessed under optimal instructional conditions.

A synthesis of the literature reveals several methodological limitations that constrain the interpretability of existing findings. First, many studies have employed short intervention periods (typically 4–6 weeks), leaving questions about sustained effects unanswered (Schroeder et al., 2018). While the present study extends this timeframe to seven weeks, it does not include a delayed posttest and therefore cannot address long-term retention; this remains a direction for future research. Second, most research has focused exclusively on reading comprehension as an outcome, neglecting theoretically related constructs such as metacognitive awareness. The present study addresses this gap by measuring metacognitive awareness as a concurrent outcome alongside comprehension. Third, the majority of research has been conducted in East Asian (Taiwan, China, Vietnam) or Iranian contexts, with no studies examining computer-assisted concept mapping in Iraqi EFL settings. This study addresses this gap by situating the investigation in the under-researched Iraqi context.

Beyond establishing whether concept mapping works, the literature has only begun to address how it works. Several mechanisms have been proposed: externalizing text structure reduces cognitive load (Sweller, 1988); hierarchical organization mirrors knowledge structures in long-term memory (Novak, 2010); and articulating propositional relationships forces deeper text processing (Kintsch, 1998). However, empirical tests of these mechanisms remain rare. The finding by Yan and Kim (2023) that digital schema instruction improved metacognitive awareness but not comprehension highlights the need to examine metacognitive processes directly. The present study addresses this gap by measuring metacognitive awareness as a

primary outcome, thereby testing the theoretical claim that concept mapping enhances comprehension partly through improving metacognitive regulation.

In summary, the existing literature establishes that concept mapping can enhance reading comprehension, but leaves critical questions unresolved: (1) Are comprehension gains accompanied by improvements in metacognitive awareness? (2) Do the benefits of concept mapping extend to the under-researched Iraqi EFL context? (3) Can a structured, seven-week computer-assisted mapping protocol produce large, practically significant effects? The present study is designed to answer these questions, thereby contributing to both the theoretical understanding of how concept mapping supports reading and the practical knowledge base for EFL instruction in Iraq.

3. Methodology

3.1. Research Design

This study employed a quasi-experimental pretest-posttest control-group design. The independent variable was instructional method (computer-assisted concept mapping vs. traditional instruction), and the dependent variables were metacognitive awareness and reading comprehension. Because the study was conducted in an authentic educational setting, intact class sections rather than individual students were assigned to the experimental and control conditions. Such an approach is common in classroom-based research, where disruption of existing class structures is undesirable. Consequently, the study employed a quasi-experimental design, and class-level factors could not be completely separated from treatment effects.

3.2. Participants

Participants included 60 first-year undergraduate Iraqi EFL students from the University of Babylon (35 male, 25 female; aged 18-22). All were native Arabic speakers with intermediate English proficiency, determined by the Oxford Placement Test. Participants were drawn from two existing reading course sections. One section was randomly assigned to the experimental condition (n = 30), and the other was assigned to the control condition (n = 30). The use of intact classes was necessary for administrative and scheduling reasons and helped preserve the natural instructional environment. Both groups had similar demographic backgrounds and had received comparable English instruction prior to the study. Informed consent was obtained from all participants. An a priori power analysis using G*Power (Faul et al., 2009) indicated that a sample of 52 participants would be sufficient to detect a large effect (f = .40) with 80% power at $\alpha = .05$ for a 2×2 mixed ANOVA, suggesting the sample of 60 was adequate.

3.3. Instruments

Oxford Placement Test (OPT): The OPT (Allan, 2004) confirmed intermediate proficiency and group equivalence ($\alpha = .84$).

Reading Comprehension Tests: Two parallel-form reading comprehension tests were developed based on IELTS Academic Reading task formats. Each test consisted of 40 items and included three reading passages, following the structure of the official IELTS exam. The passages were selected from authentic sources (e.g., academic journals, magazines, and textbooks) and covered topics appropriate for first-year university students (e.g., language, education, science, and culture). To ensure comparability between the pretest and posttest, the two forms were matched for passage length (approximately 900–1,100 words per passage), text difficulty (Flesch Reading Ease scores between 50–60), and item types (multiple choice,

matching information, true/false/not given, and sentence completion). The tests were developed by the researcher in consultation with two experienced IELTS instructors. Item difficulty was reviewed to ensure appropriateness for intermediate-level learners. Both tests were piloted with 30 Iraqi EFL students (not included in the main study) to identify problematic items and estimate reliability. The pilot resulted in minor revisions to three items. Internal consistency was acceptable for both forms (pretest KR-20 = .82; posttest KR-20 = .84), indicating satisfactory reliability.

To establish content validity, the reading passages, item types, and difficulty levels were reviewed by two experienced IELTS instructors and one applied linguistics specialist. The reviewers confirmed the appropriateness of the materials for intermediate-level Iraqi EFL learners and their alignment with the intended reading comprehension constructs. Minor revisions were subsequently made before piloting.

Metacognitive Reading Questionnaire (MRQ): A 13-item Metacognitive Reading Questionnaire (MRQ) adapted from Phakiti (2003) was used to assess students' metacognitive awareness in reading. The instrument measured three dimensions of metacognitive regulation: planning (4 items), monitoring (5 items), and evaluation (4 items). To ensure suitability for the Iraqi EFL context, the questionnaire underwent a multi-stage adaptation process. First, the original items were reviewed for linguistic clarity and cultural appropriateness, and wording was simplified where necessary. References to educational contexts not relevant to Iraqi universities were modified or removed. Second, the adapted version was reviewed by two Iraqi EFL university lecturers to establish face validity and contextual relevance. Third, the questionnaire was piloted with 30 Iraqi EFL students who were not included in the main study in order to identify ambiguous items and assess clarity. Based on pilot feedback, minor revisions were made to three items. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), yielding possible scores from 13 to 65, with higher scores indicating greater metacognitive awareness. Internal consistency was satisfactory for both the pretest ($\alpha = .86$) and posttest ($\alpha = .89$). Reliability estimates for the subscales were also acceptable: planning ($\alpha = .81$), monitoring ($\alpha = .84$), and evaluation ($\alpha = .79$), supporting the reliability of the instrument in the Iraqi EFL context.

Concept Mapping Software: The experimental group used CmapTools, receiving a 90-minute orientation. CmapTools was selected for its user-friendly interface, compatibility with university computer lab facilities, and robust features including easy editing, scalable canvases, and the ability to save and compare multiple versions.

3.4. Procedure

The seven-week intervention included weekly two-hour sessions. The experimental group followed a structured protocol:

- Pre-reading (15-20 min): Focus question introduction, skeletal map creation
- While-reading (60-70 min): Text reading, concept extraction, map construction
- Post-reading (20-30 min): Map revision, peer comparison, discussion

The control group received traditional instruction: vocabulary introduction, silent reading, teacher explanation, and comprehension questions.

Both groups completed pretests in Week 1 and posttests in Week 7. Throughout the intervention, fidelity of implementation was monitored through multiple mechanisms. The researcher maintained detailed lesson logs documenting activities, timing, and any deviations

from planned procedures. A research assistant observed 20% of sessions (selected randomly) and completed a fidelity checklist confirming adherence to the instructional protocol. Analysis of these observations indicated high fidelity (92% agreement) with no systematic differences between conditions. Instructors were not blind to condition assignment due to the nature of the intervention, but all assessments were scored by a research assistant unaware of group membership.

3.5. Data Analysis

To examine whether the intervention differentially affected comprehension at varying levels of cognitive demand, items on the reading comprehension tests were classified into three categories: literal, inferential, and evaluative. Literal items required readers to locate explicitly stated information in the text (e.g., identifying a date, fact, or definition). Inferential items required readers to combine information from different parts of the text or draw conclusions not explicitly stated (e.g., identifying an implied main idea, making predictions). Evaluative items required readers to critically assess information, judge arguments, or apply information to new contexts (e.g., evaluating the strength of an argument, identifying the author's bias). Classification was performed independently by two experienced EFL instructors. Inter-rater agreement was high (93%), and disagreements were resolved through discussion. The classification scheme was verified by a third expert (a PhD holder in applied linguistics) to ensure alignment with established taxonomies of reading comprehension (e.g., Barrett's Taxonomy). For each participant, the number of correct responses in each category was calculated separately for the pretest and posttest. Gains in each category were compared between groups using independent-samples t-tests. This analysis was exploratory and intended to generate hypotheses for future research.

Data were analyzed using SPSS version 26. Two-way mixed-design ANOVAs were conducted for each dependent variable, with Group (experimental vs. control) as the between-subjects factor and Time (pretest vs. posttest) as the within-subjects factor. Preliminary assumption checks were conducted: normality was assessed using Shapiro-Wilk tests (all $p > .05$), and homogeneity of variances was confirmed using Levene's test (all $p > .05$). Sphericity was not applicable as the within-subjects factor had only two levels. Effect sizes (partial η^2) were interpreted following Cohen (1988), with 95% confidence intervals calculated using bootstrapping (1,000 resamples).

4. Results

4.1 Metacognitive Awareness

Table 1 presents the descriptive statistics for metacognitive awareness scores across the experimental and control groups.

Table 1

Descriptive Statistics for Metacognitive Awareness Scores

Group	n	Pretest mean (SD)	Posttest mean (SD)	Mean gain	95% CI for gain
Experimental	30	36.47 (4.82)	49.13 (5.21)	12.66	[10.84, 14.48]
Control	30	35.92 (5.10)	38.27 (4.96)	2.35	[0.92, 3.78]

Note. SD = standard deviation; CI = confidence interval.

As shown in Table 1, the experimental and control groups had comparable pretest scores, while the experimental group demonstrated a substantially larger mean gain from pretest to posttest. Pretest scores showed no significant difference between groups, $t(58) = 0.44$, $p = .66$, $d = 0.11$, 95% CI [-0.40, 0.62]. The mixed ANOVA revealed significant main effects of Time, $F(1,58) = 182.47$, $p < .001$, $\eta^2_p = .76$, 95% CI [.64, .83], and Group, $F(1,58) = 61.38$, $p < .001$, $\eta^2_p = .51$, 95% CI [.32, .66]. The Group × Time interaction was significant, $F(1,58) = 61.50$, $p < .001$, $\eta^2_p = .51$, 95% CI [.32, .66]. Simple main effects analysis revealed that the experimental group improved significantly from pretest to posttest, $t(29) = 12.84$, $p < .001$, Cohen's $d = 2.48$, 95% CI [1.78, 3.18], while the control group showed no significant improvement, $t(29) = 1.92$, $p = .064$, $d = 0.47$, 95% CI [-0.04, 0.98]. Examination of subscale scores revealed that the experimental group improved across all three metacognitive components. Planning scores increased from 11.24 (SD = 1.86) to 15.67 (SD = 1.92), monitoring scores from 13.86 (SD = 2.14) to 18.43 (SD = 2.08), and evaluation scores from 11.37 (SD = 1.73) to 15.03 (SD = 1.89). All gains were statistically significant (all ps < .001) and represented large effects (ds ranging from 2.01 to 2.48).

4.2 Reading Comprehension

Table 2 provides the descriptive statistics for reading comprehension scores.

Table 2

Descriptive Statistics for Reading Comprehension Scores

Group	n	Pretest mean (SD)	Posttest mean (SD)	Mean gain	95% CI for gain
Experimental	30	21.63 (3.84)	31.47 (4.02)	9.84	[8.21, 11.47]
Control	30	21.10 (3.91)	24.20 (3.76)	3.10	[1.65, 4.55]

Note. SD = standard deviation; CI = confidence interval.

The experimental group again showed greater improvement than the control group, with a mean gain of 9.84 compared to 3.10 for the control group. Pretest scores showed no significant difference, $t(58) = 0.55$, $p = .58$, $d = 0.14$, 95% CI [-0.37, 0.65]. The mixed ANOVA revealed significant main effects of Time, $F(1,58) = 214.62$, $p < .001$, $\eta^2_p = .79$, 95% CI [.68, .85], and Group, $F(1,58) = 56.10$, $p < .001$, $\eta^2_p = .49$, 95% CI [.30, .64]. The Group × Time interaction was significant, $F(1,58) = 56.05$, $p < .001$, $\eta^2_p = .49$, 95% CI [.30, .64]. Simple main effects analysis confirmed that the experimental group made significant gains, $t(29) = 11.23$, $p < .001$, $d = 2.47$, 95% CI [1.77, 3.17], whereas the control group's improvement, while statistically significant, was substantially smaller, $t(29) = 3.94$, $p < .001$, $d = 0.81$, 95% CI [0.28, 1.34].

Analysis of item types revealed that the experimental group improved across all comprehension levels. Gains were largest for inferential items (M gain = 4.21, SD = 1.42), followed by evaluative items (M gain = 3.18, SD = 1.23) and literal items (M gain = 2.45, SD = 0.98). This pattern suggests that computer-assisted concept mapping may be particularly beneficial for higher-order comprehension processes that require integration and critical evaluation of text content.

5. Discussion

This study investigated whether computer-assisted concept mapping enhances metacognitive awareness and reading comprehension among Iraqi EFL students. The findings show that the experimental group significantly outperformed the control group on both outcomes, with large effect sizes. The discussion interprets these findings, considers alternative explanations, and integrates theoretical frameworks to explain *why* computer-assisted concept mapping may have produced these effects.

5.1. Discussion of Research Question 1: Metacognitive Awareness

The results revealed that computer-assisted concept mapping significantly enhanced students' metacognitive awareness. The experimental group demonstrated substantially greater gains than the control group across the dimensions of planning, monitoring, and evaluation, with a large effect size (η^2_p = .51). These findings suggest that computer-assisted concept mapping can serve as an effective tool for fostering metacognitive regulation during reading activities.

One possible explanation is that the structured concept-mapping process required learners to engage actively in planning, monitoring, and evaluating their understanding while reading. The pre-reading, while-reading, and post-reading stages closely corresponded to established models of metacognitive regulation (Baker & Brown, 1984; Flavell, 1979). Additionally, the digital affordances of CmapTools enabled students to revise, reorganize, and refine their maps with minimal effort, encouraging continuous reflection on their understanding rather than treating revision as a separate activity (Aşıksoy, 2019). Farrokhnia et al. (2019) similarly argue that technology-supported concept mapping promotes iterative learning processes in which learners repeatedly evaluate and modify their representations of knowledge.

The visual and hierarchical structure of concept maps may also have supported metacognitive development by making otherwise invisible cognitive processes visible and manipulable. Novak (2010) contends that concept maps externalize conceptual relationships and enable learners to monitor their understanding more effectively. In the present study, this externalization may have facilitated greater awareness of how ideas were connected within texts and how comprehension could be regulated.

The present findings are consistent with previous research. Liu et al. (2010) reported that computer-assisted concept mapping improved learners' strategic awareness and reading performance. Similarly, Khajavi and Ketabi (2012) found that concept mapping promoted strategic engagement and learner self-regulation among Iranian EFL learners. The findings also align with Bozorgian et al. (2022), who emphasized the importance of explicit strategy instruction for developing metacognitive awareness.

However, the findings differ somewhat from those reported by Yan and Kim (2023), who observed improvements in awareness that were more limited in scope. A possible explanation for this discrepancy is the longer duration of the present intervention (seven weeks vs. four weeks) and the more structured mapping procedures employed throughout the study. Differences in learner characteristics, educational contexts, and instructional implementation may also have contributed to the contrasting outcomes.

5.2. Discussion of Research Question 2: Reading Comprehension

The results indicated that computer-assisted concept mapping significantly improved students' reading comprehension (η^2_p = .49). Although both groups showed some improvement

over time, the experimental group achieved substantially greater gains, particularly on tasks requiring inferential comprehension.

These findings may be explained by the cognitive and organizational benefits of concept mapping. According to Sweller's (1988) cognitive load theory, external representations can reduce demands on working memory by organizing information in a structured format. Concept maps provide such an external representation, allowing learners to focus more attention on interpretation and integration of textual information. This explanation is consistent with Kintsch's (1998) construction–integration model, which emphasizes the importance of building coherent mental representations of text. By requiring learners to identify and label relationships among concepts, concept mapping encouraged deeper processing and inferential thinking. Furthermore, Novak (2010) argues that the hierarchical organization of concept maps mirrors the structure of knowledge in long-term memory, thereby facilitating both comprehension and retention.

The largest gains were observed on inferential items, which require the most cognitive integration (Kintsch, 1998). This pattern suggests that concept mapping particularly supports the ability to connect ideas and construct coherent situation models—a finding consistent with the theoretical mechanisms proposed above.

The present results are broadly consistent with previous studies. Liu et al. (2010) demonstrated that computer-assisted concept mapping enhanced reading comprehension among EFL learners. Likewise, Khajavi and Ketabi (2012) and Riahi and Pourdana (2017) reported that concept mapping was superior to traditional instruction in improving reading performance.

Nevertheless, the present findings contrast with those of Yan and Kim (2023), who reported improvements in strategic awareness but not in reading comprehension. One possible reason is that the current study employed a longer intervention period (seven vs. four weeks) and provided learners with repeated opportunities to revise and refine their maps. Moreover, differences in instructional design, learner proficiency, and assessment measures may account for the divergent findings.

5.3. Relationship Between Metacognitive Awareness and Reading Comprehension

Taken together, the findings suggest a close relationship between metacognitive awareness and reading comprehension. The parallel gains observed across both outcomes support theoretical perspectives that view metacognitive regulation as an important contributor to successful reading comprehension (Baker & Brown, 1984; Flavell, 1979). As Cromley (2023) argues, metacognitive awareness and reading comprehension are reciprocally related: effective regulation facilitates comprehension, while successful comprehension experiences further refine learners' metacognitive knowledge. The present findings are consistent with this perspective and suggest that computer-assisted concept mapping may have strengthened both processes simultaneously.

While the present study cannot establish causality between these two outcomes, the parallel gains suggest that computer-assisted concept mapping may have enhanced comprehension partly by improving metacognitive regulation, and enhanced metacognitive regulation partly through successful comprehension experiences. This reciprocal relationship warrants further investigation through mediation analyses or longitudinal designs.

6. Conclusion

This study demonstrated that computer-assisted concept mapping significantly enhances metacognitive awareness and reading comprehension among Iraqi EFL university students. The experimental group showed substantially greater gains than the control group, with large effect sizes indicating practical significance. These findings contribute to the limited body of research on strategy-based digital interventions in Iraqi EFL contexts.

However, these findings should be interpreted in light of several limitations. The quasi-experimental design using intact classes limits causal claims, as random assignment was not feasible. The seven-week intervention does not address long-term retention, and self-report measures may be subject to social desirability bias. The sample was limited to first-year intermediate-proficiency learners at one university, limiting generalizability. The novelty effect of the digital tool and the lack of instructor blinding may also have introduced bias. Additionally, the study did not collect systematic data on participants' prior experience with educational technology or concept mapping. A further limitation concerns the unit of assignment: because only one class represented each condition, class-level effects (e.g., group dynamics, classroom culture, scheduling) are confounded with treatment effects. Future research should address these limitations by including pre-study questionnaires to measure prior experience, employing multiple classes per condition with multilevel modeling, and incorporating delayed posttests to assess retention.

Despite these limitations, the findings have practical implications. Curriculum designers should allocate regular class time to mapping activities and develop structured protocols (pre-reading, while-reading, post-reading) that scaffold metacognitive processes. Teachers require training in both technical aspects and metacognitive principles, supported by professional learning communities. Institutions must ensure adequate technology infrastructure, including computer laboratories, technical support, and contingency plans. Beyond instruction, concept mapping offers formative assessment opportunities, revealing misconceptions and gaps in understanding that traditional comprehension questions may miss. The revision history features of computer-assisted mapping software can also document learning progress.

Future research should include longitudinal studies to assess retention, investigations across different proficiency levels, and collaborative mapping configurations. Mixed-method designs (e.g., think-aloud protocols), cross-cultural comparisons, and experimental comparisons between computer-assisted and paper-based mapping are also needed.

In summary, computer-assisted concept mapping offers a promising alternative to traditional instruction in Iraqi EFL contexts. Students exposed to the approach demonstrated substantial gains. With appropriate support and well-designed instruction, learners in similar contexts may develop the metacognitive awareness and reading proficiency essential for academic success.

Conflict of interest

The authors declare no conflicts of interest.

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