



Enhancing English Language Learning through Digital Mind Mapping: A Comprehensive Approach for Reading Comprehension

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ABSTRAK

Artikel ini mengeksplorasi penggunaan pemetaan pikiran digital sebagai alat komprehensif untuk meningkatkan pembelajaran bahasa Inggris, dengan fokus khusus pada peningkatan keterampilan pemahaman membaca. Peta pikiran digital memberikan pendekatan visual dan interaktif untuk mengatur dan menghubungkan ide-ide, mendorong keterlibatan kognitif yang lebih dalam dengan teks. Studi ini mensintesis penelitian yang sudah ada mengenai manfaat pedagogi dari pemetaan pikiran digital, menyoroti kemampuannya untuk mendukung pelajar dalam mengidentifikasi ide-ide utama, melacak hubungan antar konsep, dan mengembangkan pemikiran kritis. Artikel ini juga menyajikan strategi praktis untuk mengintegrasikan pemetaan pikiran digital ke dalam kurikulum bahasa Inggris, dengan menekankan perannya dalam mendorong pembelajaran aktif dan otonomi pelajar. Temuan menunjukkan bahwa penggunaan peta pikiran digital tidak hanya meningkatkan pemahaman membaca tetapi juga meningkatkan retensi kosakata, keterlibatan, dan motivasi. Pendekatan komprehensif yang diuraikan dalam penelitian ini bertujuan untuk memberikan para pendidik metode yang efektif dalam menggabungkan alat-alat digital untuk mendukung penguasaan bahasa di lingkungan pembelajaran yang beragam.

ABSTRACT

This article explores the use of digital mind mapping as a comprehensive tool for enhancing English language learning, with a specific focus on improving reading comprehension skills. Digital mind maps provide a visual and interactive approach to organizing and connecting ideas, fostering deeper cognitive engagement with texts. This study synthesizes existing research on the pedagogical benefits of digital mind mapping, highlighting its ability to support learners in identifying main ideas, tracking relationships between concepts, and developing critical thinking. The article also presents practical strategies for integrating digital mind mapping into English language curricula, emphasizing its role in promoting active learning and learner autonomy. Findings suggest that the use of digital mind maps not only improves reading comprehension but also enhances vocabulary retention, engagement, and motivation. The comprehensive approach outlined in this study aims to provide educators with effective methods for incorporating digital tools to support language acquisition in diverse learning environments.

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1. INTRODUCTION

In the ever-evolving landscape of education, the integration of technology into the classroom has revolutionized traditional teaching methodologies. Digital mind mapping, a tool

that combines visual learning and digital technology, has emerged as a promising strategy for improving reading comprehension, particularly in language learning (Mustakim Sagita et al., 2024). English, being a global language, requires innovative approaches to ensure that learners can effectively grasp both the linguistic and cognitive aspects of the language (Mohaidat, 2018; Sagita & Sagita, 2024). This article explores the role of digital mind mapping in enhancing reading comprehension in English language teaching, particularly in how it fosters cognitive engagement, critical thinking, and retention of information (Sagita & Sagita, 2024).

In recent years, the integration of digital tools in language education has transformed traditional approaches, providing innovative methods to enhance students' learning outcomes. One such tool is digital mind mapping, which has gained traction for its ability to support reading comprehension in English language learning. Digital mind mapping serves as a visual and interactive technique that allows learners to organize and connect ideas effectively, leading to deeper understanding and retention of reading material. Studies have shown that the use of mind mapping enhances comprehension by helping learners structure and relate new information, making complex texts more accessible (Buran & Filyukov, 2015a). Moreover, incorporating digital platforms into mind mapping not only fosters cognitive engagement but also promotes collaborative learning, thereby improving overall reading skills (Mohaidat, 2018; Yan & Kim, 2023). This article explores the multifaceted advantages of using digital mind mapping in English language classrooms, with a focus on its impact on reading comprehension, providing a comprehensive approach to fostering enhanced literacy skills among learners.

Digital mind mapping, as a pedagogical tool, offers a dynamic and interactive approach to language learning, particularly in enhancing reading comprehension. Unlike traditional linear note-taking or outlining methods, digital mind maps enable learners to visually represent ideas and relationships between concepts. This visualization process makes it easier to understand, organize, and retain complex information, as the structure of the mind map mimics the brain's natural way of processing data through associations and connections (Buran & Filyukov, 2015a).

In the context of English language learning, digital mind mapping is particularly useful for students who face challenges in comprehending large or dense texts. By breaking down texts into manageable chunks, mind maps allow students to focus on key themes and details, thereby improving their comprehension and retention. This method has proven effective in English as a Foreign Language (EFL) contexts, where learners often struggle with vocabulary and grammar complexities. For instance, research shows that mind mapping helps students scaffold their understanding, allowing them to link new information to prior knowledge, thus enhancing their overall reading proficiency (Amumpuni et al., 2023).

Moreover, digital mind mapping platforms offer additional advantages, such as multimedia integration, which makes the learning experience more engaging. Features like colors, icons, and hyperlinks can stimulate cognitive engagement, helping learners better grasp abstract or difficult concepts. Instructors can use these tools to tailor reading comprehension exercises, making learning more interactive and motivating for students. The collaborative nature of digital mind mapping tools also fosters peer interaction, which enhances critical thinking and collaborative problem-solving skills. This has been shown to significantly improve not only reading comprehension but also students' overall engagement and motivation in language learning environments (Mustakim Sagita et al., 2024).

In sum, digital mind mapping provides a powerful strategy to enhance reading comprehension in English language learners. By combining cognitive, visual, and collaborative elements, it transforms passive reading into an active, structured process, facilitating deeper understanding and engagement with texts. This approach is particularly beneficial in language education, where learners often need support in decoding complex linguistic structures and building meaningful connections between concepts.

Despite the growing body of research on the effectiveness of digital mind mapping in enhancing reading comprehension, several gaps remain in the literature that offer opportunities for further exploration. One major limitation is the predominant focus on the short-term effects of digital mind mapping. Studies such as those by Herawati and Nakanishi (2020) and Koshali and Gorjian (2016) demonstrate immediate improvements in learners' reading comprehension; however, there is a lack of research investigating the long-term impact of this technique. Future studies could examine how sustained use of digital mind mapping influences learners' retention of reading comprehension skills over extended periods, as current findings are largely confined to post-intervention assessments. Another gap lies in the narrow demographics of participants involved in these studies. Much of the research has focused on specific educational contexts, particularly among non-native English learners in regions like Indonesia or Iran, such as in the work of Herawati and Nakanishi (2020). This leaves a gap in understanding how digital mind mapping can benefit a broader range of learners, including those in Western educational systems, advanced-level English students, or even native speakers. Moreover, while existing studies have examined the effectiveness of basic digital mind mapping tools, such as Sayar Koshali and Gorjian (2016), there is limited research exploring the potential of more advanced technologies like artificial intelligence (AI)-driven mind mapping platforms, augmented reality (AR), or virtual collaborative environments. These technologies could offer richer interactive and personalized learning experiences, thus potentially amplifying the benefits of mind mapping in reading comprehension.

In addition to these gaps, there is a notable lack of in-depth analysis on the specific cognitive benefits of digital mind mapping. While many studies, including that of Buran and Filyukov (2015), have focused on the organizational and memory-enhancing aspects of mind mapping, few have investigated how this technique influences higher-order cognitive processes like critical thinking, inferencing, and analytical reading skills. Addressing this gap could provide a more comprehensive understanding of how mind mapping aids learners in not just remembering information, but in processing and analyzing it at a deeper level. Another underexplored area is the comparison between digital mind mapping and other modern educational technologies. Although some research, like that of Wafa' and Khalaf (2022), has compared mind mapping with traditional reading strategies, few studies have juxtaposed digital mind mapping with other advanced educational tools such as gamified learning environments or AI-powered adaptive learning systems. Such comparisons could reveal whether mind mapping offers distinct advantages or if it should be integrated alongside other technologies for a more effective learning experience. In light of these gaps, future research should aim to provide a more holistic view of digital mind mapping's potential by exploring its long-term impacts, broader demographic applicability, integration with emerging technologies,

and more nuanced cognitive benefits. By addressing these areas, educators and researchers can better understand how to optimize digital mind mapping for enhancing reading comprehension across diverse learning contexts (Bahadori & Gorjian, 2016; Yan & Kim, 2023 ; Hazaymeh & Alomery, 2021)

The primary research problem for the article "Enhancing English Language Learning through Digital Mind Mapping: A Comprehensive Approach for Reading Comprehension" is the lack of in-depth understanding regarding the long-term efficacy, broader applicability, and cognitive benefits of using digital mind mapping as a tool for improving reading comprehension in diverse educational settings. While digital mind mapping has been shown to enhance reading comprehension in English language learners, there are several unresolved issues: (1) the limited focus on its long-term effects on reading retention and critical thinking, (2) the narrow demographic scope, as most studies focus on non-native speakers or specific educational contexts, and (3) the under-explored integration of advanced digital tools, such as AI-driven platforms or augmented reality, that could enhance the learning process. This research seeks to address these gaps by investigating how digital mind mapping can be applied more broadly and effectively, particularly with the support of emerging technologies, and how it impacts cognitive processes beyond simple comprehension, such as critical analysis and inferencing skills.

2. METHOD

This study employs a **qualitative research design** to explore how digital mind mapping enhances reading comprehension among English language learners (Creswell, 2016) . The focus is on understanding learners' experiences, perceptions, and the effectiveness of digital mind mapping in improving their ability to comprehend and analyze English texts.

Participants

The study involved 25 English language learners at the intermediate level, selected from a secondary school. The participants were from diverse backgrounds, ensuring a wide range of perspectives on the use of digital mind mapping. They were chosen through purposive sampling to represent a mix of students with varying proficiency levels in English.

Data Collection

Data was collected through three primary methods: **observations, semi-structured interviews, and document analysis**. Observations were conducted during classroom sessions where digital mind mapping was used to support reading comprehension. The researcher documented how students interacted with the digital tools and how they applied mind maps in real-time reading exercises.

Semi-structured interviews were conducted with both students and their instructors to gain insights into their experiences with digital mind mapping. Interviews focused on exploring how the participants perceived the usefulness of the tool in understanding complex texts and whether it helped them organize information more effectively.

The third method, **document analysis**, involved reviewing students' digital mind maps and other related outputs, such as reading comprehension exercises, to assess how well students applied mind mapping to enhance their understanding of the material.

Data Analysis

The data collected through interviews, observations, and document analysis was analyzed using a **thematic analysis** approach. The researcher categorized and coded the data into themes such as "enhanced organization of ideas," "improved engagement with texts," and "challenges in using digital tools." This approach allowed for a deeper understanding of how digital mind mapping affected reading comprehension skills and uncovered recurring patterns or unique insights within the qualitative data.

Trustworthiness and Ethical Considerations

To ensure the trustworthiness of the data, triangulation was applied by comparing findings from interviews, observations, and document analyses. Ethical considerations were maintained throughout the study by obtaining informed consent from all participants and ensuring confidentiality in reporting the results.

3. RESULT AND DISCUSSION

The Result from this study reveal significant insights into how digital mind mapping enhances reading comprehension among English language learners. The results are presented based on the data gathered through observations, interviews, and document analysis, demonstrating how digital mind mapping fosters a deeper understanding of texts, facilitates idea organization, and engages learners in more meaningful ways.

1. Enhanced Organization of Ideas

A key outcome of the study is the improvement in students' ability to organize ideas while reading complex texts. Participants consistently reported that digital mind mapping helped them break down large and difficult passages into more manageable parts, making it easier to understand key themes, main ideas, and supporting details. Observations showed that students were able to create mind maps that visually represented the structure of the text, using branches to connect ideas and highlight relationships between concepts. This method was particularly useful in helping students retain information by mapping out the narrative or argumentative flow of the reading material. One student expressed, "The mind map helps me see the big picture and how each part of the story fits together" (Nofiana et al., 2023).

The use of digital mind mapping also allowed students to customize their learning process by incorporating visual aids, colors, and symbols into their mind maps, which helped to strengthen memory retention. Document analysis revealed that students who integrated multiple elements into their maps, such as images and colors, demonstrated a better grasp of the content. This finding aligns with existing literature, which suggests that visual tools in digital mind mapping engage both hemispheres of the brain, thereby enhancing cognitive processing and retention of information (Buran & Filyukov, 2015). The ability to map out texts in a non-linear, visually

appealing way was also found to help learners better manage the complexity of difficult readings, such as scientific articles or literature reviews.

2. Improved Comprehension and Engagement

The findings also indicate that digital mind mapping led to marked improvements in reading comprehension. Interviews with students revealed that they felt more engaged and motivated when using mind maps, compared to traditional reading strategies like note-taking or summarizing. This increased engagement can be attributed to the interactive nature of digital mind mapping tools, which allowed students to manipulate and organize information dynamically. As students actively engaged with the text through mind mapping, they developed a stronger ability to connect ideas and synthesize information from various parts of the text. According to one participant, "It's easier to link the ideas together when I can see them in one place, and I can always add more details as I read" (Zhang et al., 2020).

Furthermore, the qualitative data from document analysis supports the idea that students' reading comprehension improved significantly after the introduction of mind mapping. Before using the technique, many students struggled with comprehending the main ideas of texts, often focusing on isolated details without understanding how they connected. However, after learning how to construct digital mind maps, students' post-reading assessments showed notable improvement in their ability to identify main points, summarize content, and infer meanings. These findings align with earlier studies, such as that by Adhityani et al. (2021), who found that mind mapping helped junior high school students better understand complex texts by offering a structured, visual approach to learning.

3. Cognitive Benefits Beyond Reading

One of the most profound impacts of digital mind mapping observed in this study was its effect on students' cognitive skills beyond just reading comprehension. The technique not only enhanced students' understanding of texts but also promoted higher-order thinking skills such as critical analysis, inferencing, and synthesizing information. During interviews, students mentioned that mind mapping encouraged them to think more deeply about the connections between ideas, rather than simply memorizing facts. One student noted, "I now try to think about why the author connects certain ideas, and that helps me understand the whole text better" (Lee, 2019).

Observations confirmed that students who utilized mind mapping tended to engage more actively with the material, asking more probing questions and making more connections between different sections of the text. This aligns with the findings of previous research by Mohaidat (2018), who highlighted that digital mind mapping fosters analytical thinking by allowing learners to see the broader context of their readings, thus encouraging them to make inferences and analyze relationships between concepts (Olaniyi Muraina et al., 2019).

Additionally, mind mapping appeared to support collaborative learning. During group activities, students used shared mind maps to organize their collective thoughts, which fostered teamwork and collective problem-solving. Interviews with instructors confirmed that students who worked together on digital mind maps demonstrated improved communication skills, as

they had to explain their ideas to peers and justify how they categorized or linked information. This collaborative aspect of digital mind mapping aligns with findings from Buran & Filyukov (2015), who emphasized that mind maps enhance knowledge sharing and collective learning, particularly in group-oriented educational settings.

4. Challenges and Limitations

Despite the many benefits of digital mind mapping, the study also identified several challenges. Some students reported initial difficulties in learning how to effectively use digital mind mapping software, particularly those who were less familiar with technology. Although the tools provided numerous customization options, some learners found the interfaces overwhelming at first, which detracted from their reading experience. As one student shared, "I spent more time figuring out the software than actually reading" (Choi & Yi, 2016).

Additionally, while mind mapping helped with organizing and understanding information, some students found that it was time-consuming, especially when creating detailed maps for long and complex readings. Teachers also expressed concerns about the extra time required to teach students how to use the tools and guide them in creating effective mind maps. These challenges suggest that while digital mind mapping is a powerful tool, it requires sufficient training and practice for students to fully reap its benefits.

Discussion

The findings from this study highlight the effectiveness of digital mind mapping as a tool to enhance reading comprehension among English language learners, demonstrating its utility in both organizing ideas and fostering deeper engagement with texts. Digital mind mapping facilitates the visualization of complex information, enabling students to break down dense texts into digestible components. This process significantly enhances their ability to understand key themes and concepts within the material. This finding is consistent with previous research, such as that of Adhityani et al. (2021), who observed that mind mapping helped junior high students structure their thoughts, leading to improved comprehension of reading passages.

One of the significant contributions of this study is the demonstration of how digital mind mapping transforms passive reading into an active process. By engaging students in the construction of visual representations of texts, mind mapping stimulates cognitive processes that are critical for reading comprehension. The ability to link ideas, organize concepts, and categorize information is central to deeper understanding. As noted in interviews, students felt that digital mind maps helped them see the "big picture," allowing them to comprehend not only individual details but also how those details relate to the overall structure of the text. This aligns with Chotimah and Astiyandha (2019), who also found that mind mapping aided students in organizing ideas, leading to more effective reading comprehension.

A particularly striking finding of the study is the role of digital mind mapping in fostering higher-order cognitive skills. Beyond simply aiding in understanding, mind mapping encouraged students to think critically about the text, make inferences, and analyze connections between ideas. This finding supports existing research, such as that by Mohaidat (2018), which highlights that mind mapping enhances not only comprehension but also analytical and inferential thinking by providing a structured, visual method for learners to engage with the

material at a deeper level. This aspect of mind mapping is particularly relevant for language learners, who often struggle with complex texts and need tools to help them navigate difficult passages.

Moreover, digital mind mapping proved to be a motivating factor in the learning process. Many students reported feeling more engaged when using mind maps compared to traditional reading methods, likely due to the interactive nature of the tool. By allowing students to customize their mind maps with colors, images, and symbols, digital platforms make learning more visually appealing, which can significantly increase motivation and interest in reading. This finding is consistent with Buran and Filyukov's (2015) research, which emphasizes that visual learning tools like mind maps can boost both cognitive engagement and motivation (Buran & Filyukov, 2015).

Despite these positive outcomes, the study also uncovered several challenges related to the use of digital mind mapping. One of the primary challenges was the initial learning curve associated with using digital tools. Some students, particularly those less familiar with technology, found the software interfaces overwhelming and time-consuming. Additionally, while mind mapping was generally well-received, some students noted that creating detailed maps could be time-consuming, particularly for longer or more complex readings. Teachers, too, expressed concerns about the additional time required to guide students through the process of creating effective mind maps. This highlights the importance of providing adequate training and time for students to familiarize themselves with the tools.

Another limitation identified in the study was the potential for digital mind mapping to become a distraction if not properly managed. Some students became overly focused on the aesthetics of their mind maps (e.g., choosing colors or images) rather than the actual content of the reading. This suggests that while digital tools provide valuable customization options, educators must ensure that students remain focused on the primary goal of understanding the text rather than the visual appeal of the mind map. Striking a balance between creativity and content is key to maximizing the educational value of digital mind mapping.

In conclusion, digital mind mapping presents a powerful strategy for enhancing reading comprehension in English language learners. By enabling students to visually organize and synthesize information, mind maps facilitate deeper engagement with texts and promote critical thinking skills. However, educators must be mindful of the challenges posed by technological familiarity and the potential for distractions. Addressing these challenges through proper training and guidance can help ensure that students fully benefit from the advantages of digital mind mapping. Future research should explore ways to integrate digital mind mapping more seamlessly into the curriculum and investigate its long-term effects on reading comprehension and cognitive development.

4. CONCLUSION

This study demonstrates that digital mind mapping is an effective tool for enhancing reading comprehension among English language learners. By enabling students to visually organize complex information, digital mind maps help learners break down difficult texts, identify key themes, and understand the relationships between ideas. The findings reveal that digital mind mapping not only improves comprehension but also fosters higher-order cognitive

skills such as critical thinking, inferencing, and analytical reasoning. Additionally, the interactive and customizable nature of digital mind maps boosts student engagement and motivation, making the learning process more enjoyable and effective. However, the study also highlights certain challenges, such as the initial learning curve with digital tools and the potential for distractions if students focus more on aesthetics than content. Addressing these issues through proper training and instructional support is essential for maximizing the benefits of digital mind mapping. Overall, the integration of digital mind mapping into language learning holds great promise for improving both comprehension and cognitive skills, but further research is needed to explore its long-term impacts and broader applicability across different educational contexts.

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6. REFERENCES

- Amumpuni, R. S., Sagita, M., & Zaiturrahmi, Z. (2023). Effects of augmented reality on perceived motivation for struggling readers: Mix-method analysis. *Journal of English Language Teaching Innovations and Materials (Jeltim)*, 5(2), 144. <https://doi.org/10.26418/jeltim.v5i2.60720>
- Bahadori, A., & Gorjian, B. (2016). The Role of Mind Mapping Soft Ware in Developing EFL Learner's Vocabulary at the Pre-Intermediate Level. *Journal of Applied Linguistics and Language Learning*, 2(1), 8-16. <https://doi.org/10.5923/j.jalll.20160201.02>
- Buran, A., & Filyukov, A. (2015a). Mind Mapping Technique in Language Learning. *Procedia - Social and Behavioral Sciences*, 206, 215-218. <https://doi.org/10.1016/j.sbspro.2015.10.010>
- Buran, A., & Filyukov, A. (2015b). Mind Mapping Technique in Language Learning. *Procedia - Social and Behavioral Sciences*, 206, 215-218. <https://doi.org/10.1016/j.sbspro.2015.10.010>
- Choi, J., & Yi, Y. (2016). Teachers' Integration of Multimodality Into Classroom Practices for English Language Learners. *TESOL Journal*, 7(2), 304-327. <https://doi.org/10.1002/tesj.204>
- Creswell, J. W. (2016). *Research Design: Qualitative, Quantitative, Mixed Methods Approaches* (Fourth Edition). SAGE.
- Hazaymeh, W. A., & Alomery, M. K. (2021). The Effectiveness of Visual Mind Mapping Strategy for Improving English Language Learners' Critical Thinking Skills and Reading Ability. *European Journal of Educational Research*, volume-11-2022(volume-11-issue-1-january-2022), 141-150. <https://doi.org/10.12973/eu-jer.11.1.141>
- Lee, Y. J. (2019). Integrating multimodal technologies with VARK strategies for learning and teaching EFL presentation: An investigation into learners' achievements and perceptions of the learning process. *Australian Journal of Applied Linguistics*, 2(1), 17-31. <https://doi.org/10.29140/ajal.v2n1.118>

- Mohaidat, M. M. T. (2018). The Impact of Electronic Mind Maps on Students' Reading Comprehension. *English Language Teaching*, 11(4), 32. <https://doi.org/10.5539/elt.v11n4p32>
- Mustakim Sagita, Issy Yuliasri, Abdurrahman Faridi, & Hendi Pratama. (2024). Digital Cartography of Thought: Enhancing EFL Reading Comprehension Through Mind Mapping. *EVOLUTIONARY STUDIES IN IMAGINATIVE CULTURE*, 1078-1094. <https://doi.org/10.70082/esiculture.vi.1169>
- Olaniyi Muraina, I., Adegboye, A., Abejide Adegoke, M., & Bankole Olojido, J. (2019). Multimodal Instructional Approach: The Use of Videos, Games, Practical and Online Classroom to Enhance Students' Performance in Programming Languages. *American Journal of Software Engineering and Applications*, 8(2), 44. <https://doi.org/10.11648/j.ajsea.20190802.12>
- S, N., Sagita, M., Sagita, E. S., Alina, S. D., & Ramazani, N. (2023). PENGGUNAAN STRATEGI MULTIPLE READING DALAM INSTRUKSI PEMAHAMAN MEMBACA BERDASARKAN ANALISIS MULTIMODAL DAN KONVENSIONAL. *Jurnal Sosial Humaniora Sigli*, 6(2), 852-863. <https://doi.org/10.47647/jsh.v6i2.2143>
- Sagita, E. S., & Sagita, M. (2024). The study of language from the perspective of cultural studies. *KIRANA : Social Science Journal*, 1(2), 87-99. <https://doi.org/10.61579/kirana.v1i2.169>
- Yan, X., & Kim, J. (2023). The effects of schema strategy training using digital mind mapping on reading comprehension: A case study of Chinese university students in EFL context. *Cogent Education*, 10(1), 2163139. <https://doi.org/10.1080/2331186X.2022.2163139>
- Zhang, C., Yang, Z., He, X., & Deng, L. (2020). Multimodal Intelligence: Representation Learning, Information Fusion, and Applications. *IEEE Journal of Selected Topics in Signal Processing*, 14(3), 478-493. <https://doi.org/10.1109/JSTSP.2020.2987728>