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The Perception and Effectiveness of Digital Mind Maps in Improving Student Understanding of Science Concepts in Learning: A Systematic Literature Review

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Abstract

In the era of digital education, visual and interactive approaches such as digital mind maps are gaining increasing attention in efforts to enhance students' understanding of abstract and complex scientific concepts. This study aims to explore the perception of teachers and students as well as to assess the effectiveness of using digital mind maps in improving mastery of science concept, particularly among primary school pupils. This study adopts systematic literature review methodology by the PRISMA framework, which encompasses four main phases identification, screening, eligibility and inclusion. A total 37 articles from Scopus, Web of Sciences and Google Scholar data bases published between 2021 and 2025 were analyzed.The finding indicate that digital mind maps not only enhance the understanding of science concept through structured visuals but also support teachers' instructional strategies and students' self-directed learning. Teachers utilize mind maps as teaching aids that reinforce textbook content and foster critical learning while students use them to strengthen memory and understanding through concept connections. This study recommends that the integration of technology in the creation of digital mind maps be widely continued as it has the potential to support inquiry-based and collaborative pedagogy in science education.

Keywords: Digital Mind Maps, Science Concept, Student Perception, Teacher Strategies, Conceptual Understanding

Introduction

Science Education plays a crucial role in shaping a generation of scientifically literate and capable of critical, creative, and problem-solving thinking. However, within the context of teaching and learning in primary schools, there are significant challenges in ensuring that students understand and master scientific concepts. A study by Zulkifli and Wahab (2013) found that the use of mind maps in teaching and learning can help students to understand the subject matter in a structured and systematic way.

Digital mind maps represent an innovative visual approach that allows students to build relationships between concepts in a more structured way. The use of digital mind maps in forms such as Canva and interactive platforms like Padlet allows students to collaborate and construct understanding in a more meaningful way. A study by Wan Nor Syazwani et al. (2024) found that the use of Canva in learning design increased student interest and focus on learning materials. Meanwhile, Rosli and Rahmab (2022) also demonstrated that the use of Padlet in science teaching and learning enhances student engagement.

Furthermore, the use of digital mind maps has also had a positive impact in various fields of education. A study by Mustika et al. (2025), in the context of primary school students' creative writing, showed an increase in students' fluency, authenticity, and sensitivity when using mind maps as a pre-writing activity.

In an even more interactive context, a study by Chiu and Hwang (2024) combines mind maps with a robotics-based learning approach, and found that this approach is effective in enhancing students' critical and creative thinking. This shows that the combination of technology and visual methods such as mind maps can generate more stable learning.

This study was conducted to systematically explore and contribute to the improvement of concept mastery. It also aims to understand how it is received by the main users, namely teachers and students.

Research Challenges

Mastering fundamental concepts in Science is a crucial component that lays the foundation for students' scientific literacy. However, the reality is that many primary school students struggle to grasp abstract scientific concepts. The inability to connect facts and concepts often leads to misunderstandings, disinterest, and poor academic performance (Khan, Taj & Younas, 2024).

This challenge stems from traditional teaching approaches that are still teacher-centered and lack the use of visual and interactive strategies to deliver learning content. Previous research has shown that students who learn through visual methods, such as mind maps, demonstrate improved understanding and information organization skills. However, the manual creation of mind maps without guidance or technological support can be less engaging and difficult for students to independently access.

Furthermore, educational technologies such as Canva and Padlet are increasingly being introduced in schools, but their use in creating digital mind maps is not fully explored. Teachers still lack training on effectively integrating technology into their teaching and learning, and students have not yet been able to fully utilize the potential of digital mind maps to deeply and meaningfully understand science content.

In Malaysia, there is a lack of comprehensive research on the perceptions of both teachers and students regarding the use of mind maps and their effectiveness in improving science understanding, particularly among primary school students.

Therefore, a systematic literature review is needed to investigate how digital mind maps can be used effectively, how they are perceived by users in the classroom, and what the best strategies are for improving science understanding through this approach.RESEARCH OBJECTIVES

This study is conducted to achieve the following objectives:
1. To evaluate the impact of using guided digital mind maps on students' memory and understanding of science concepts.
2. To explore students' and teachers' perceptions of the effectiveness of guided digital mind maps in supporting student learning.

Research Methodology

The research methodology follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, encompassing four key phases:

1. Identification - Articles are identified through searches in selected databases using specific keywords.
2. Screening - Duplicate articles are removed, and a preliminary screening is conducted based on titles and abstracts.
3. Eligibility - A thorough assessment of article suitability is performed through full-text review.
4. Inclusion - Articles that meet the criteria are included in the thematic analysis.

This standard provides a transparent, systematic, and reproducible approach to conducting Systematic Literature Reviews (SLRs). This is crucial because it demonstrates the integrity of the research process, minimizes selection bias, and enhances the credibility and reliability of Systematic Literature Reviews.

Identification

Reputable databases such as Scopus, Web of Science, and Google Scholar are used for systematic searching for relevant articles. The search yielded 283 publications, representing a total of 120 publications from Scopus, 135 publications from Web of Science, and 28 publications from Google Scholar.

Table 1
Search in the database

Pangkalan data	Search strings
Scopus	TITLE-ABS-KEY (mind AND mapping) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Mind Mapping"))
Web Of Science	TS={{mind mapping digital learning
Google Scholar	Type name of article

Screening

The screening phase is the second stage in the Systematic Literature Review (SLR) process, following identification. Its purpose is to filter out articles that have been identified as irrelevant or redundant, so that only relevant and unique articles proceed to the eligibility screening stage. This resulted in 116 publications being removed from the list. The remaining publications will then undergo a screening process, where only those that meet the criteria will be selected. This process will allow for 50 articles to proceed to the eligibility screening stage.

Table 2

Selection and Exclusion Criteria for Journal Articles

Category	**Inclusion Criteria**	**Exclusion Criteria**
Publication Year	2021-2025	2020 and earlier
Language	English and Malay	Language other than English and Malay
Publication Type	Journal Articles	Paid-access Publications

Eligibility

Our selection process aims to ensure that only articles meeting our inclusion criteria are included in the final analysis. All articles that have passed the initial screening will be thoroughly evaluated through a full text review to determine their suitability for the scope of the study. This process identified 42 articles that met the criteria for thematic analysis. These articles were then coded, categorized, and synthesized to identify themes related to the perceptions and effectiveness of using mind maps in science teaching and learning.

Assessing the Quality of Research Articles

To ensure that the research articles analyzed meet high quality standards and adhere to research guidelines, this study used the MMAT (Mixed Methods Appraisal Tool) to assess the quality of the methodologies of the selected articles. MMAT is a tool specifically designed to evaluate the validity of both quantitative, qualitative, and mixed methods research methodologies.

MMAT was used in the study for the following purposes:

i. To evaluate the quality of the original design of each article.

ii. To identify any weaknesses in terms of sampling, data analysis, and the validity of the results.

iii. To determine the suitability of the articles for thematic analysis in this review.

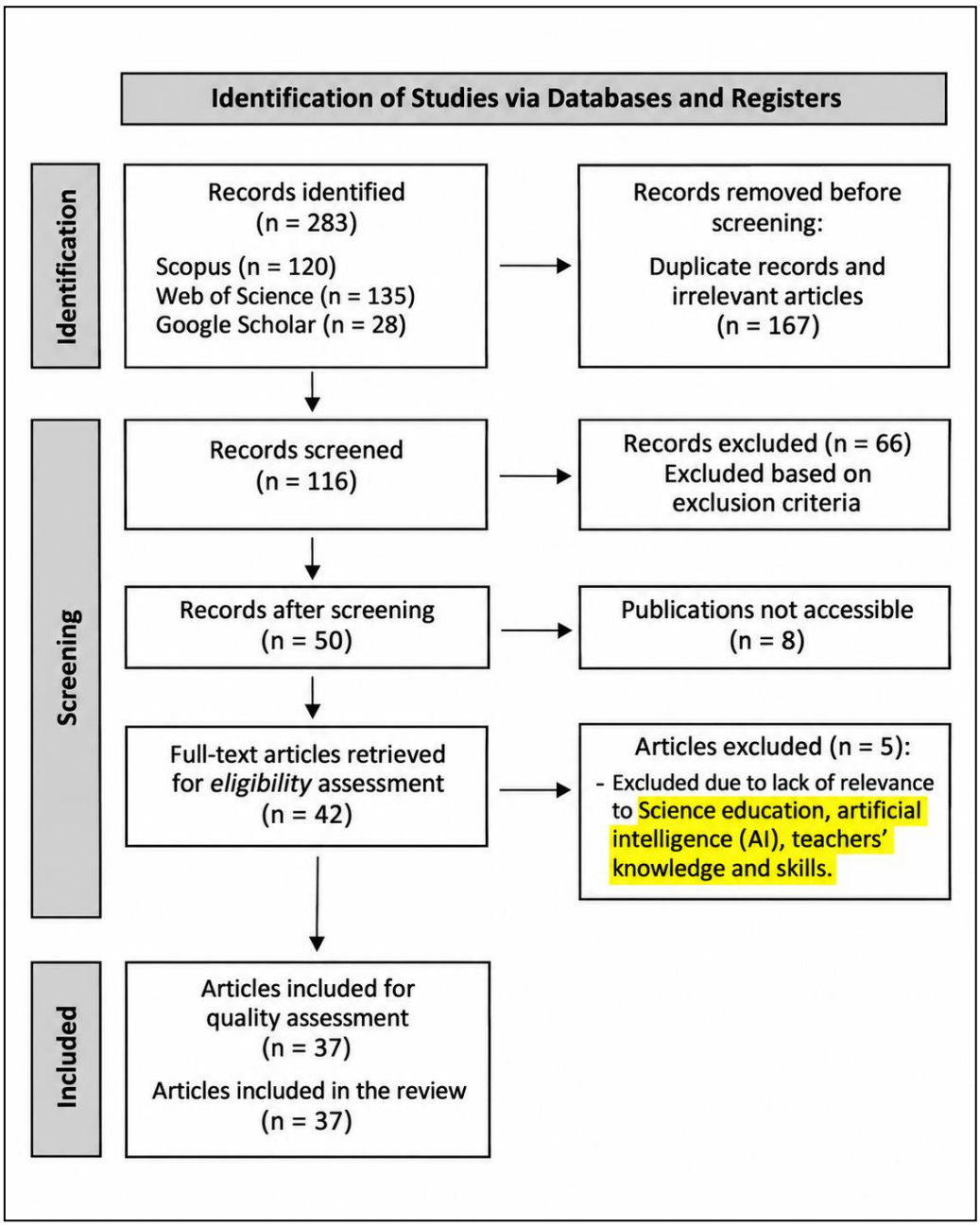


Figure 1: Adapted PRISMA Systematic Literature Review Flow Diagram, based on Page et al. (2021)Table 3: Article Quality Assessment Results

No	Authors (Year)	Country	Types of Research	Journal	QA 1	QA 2	QA 3	QA 4	QA 5	Required Criteria for Acceptance	Inclusion
1	Shahida Munir et al. (2023)	Pakistan	QN	Research Journal for Societal Issues	✓	✓	✓	✓	✓	5	Acceptance
2	Sana Khan et al. (2024)	Pakistan	QN	Uncertain	✓	✓	✓	✓	✓	5	Acceptance
3	Nyagblor mase et al. (2021)	Ghana	QN	Studies in Learning and Teaching	✓	✓	✓	✓	✓	5	Acceptance
4	Dennis Fung & Tim Liang (2023)	Hong Kong	QN	International Journal of Science and Mathematics Education	✓	✓	✓	✓	✓	5	Acceptance
5	Debbag et al. (2021)	Turkey	QL	Informatics in Education	✓	✓	✓	✓	✓	5	Acceptance
6	Nurhikm ah Hasyim et al. (2024)	Indonesia	QN	Cogent Education	✓	✓	✓	✓	✓	5	Acceptance
7	Min-Chi Chiu & Gwo-Jen Hwang (2024)	Taiwan	QN	Education and Information Technologies	✓	✓	✓	✓	✓	5	Acceptance
8	Rafidah Abd Karim & Ramlee Mustaph a (2022)	Malaysia	QN	Journal of Technical Education and Training	✓	✓	✓	✓	✓	5	Acceptance
9	Yinghui Shi et al. (2023)	China & Canada	QN	Asia Pacific Education Review	✓	✓	✓	✓	✓	5	Acceptance
10	Menglin Fang et al. (2024)	UAE, China, Russia	QN	BMC Psychology	✓	✓	✓	✓	✓	5	Acceptance

11	Rais & Zulfa (2024)	Indonesia	QN	Journal of Social Science Utilizing Technology	✓	✓	✓	✓	✓	5	Acceptance
12	Parinduri (2023)	Indonesia	QL	Jurnal Inovasi Pendidikan Sains dan Terapan	✓	✓	✓	✓	✓	5	Acceptance
13	Ramadha ni et al. (2023)	Indonesia & Tanzania	QL	Child Education Journal	✓	✓	✓	✓	✓	5	Acceptance
14	Hasbolla h et al. (2023)	Malaysia	QN	Regional TVET Conference – ReTVET	✓	✓	✓	✓	✓	5	Acceptance
15	Yasir et al. (2023)	Malaysia	QN	Innovative Teaching and Learning Journal	✓	✓	✓	✓	✓	5	Acceptance
16	Esther Emma & Ruhizan (2024)	Malaysia	QN	Malaysian Journal of Social Sciences and Humanities (MJSSH)	✓	✓	✓	✓	✓	5	Acceptance
17	Shalma Hudi Cahyani & Agustina T.A.H. (2024)	Indonesia	QN	Journal on Education	✓	✓	✓	✓	✓	5	Acceptance
18	Nita Agustina et al. (2025)	Indonesia	MX	Journal of Integrated Elementary Education	✓	✓	✓	✓	✓	5	Acceptance
19	Wan Nor Syazwani	Malaysia	QN	Life Lessons	✓	✓	✓	✓	✓	5	Acceptance
	et al. (2024)			Seminar (SPSH2024)							

20	Eglė Selevičie nė (2023)	Lithuania	MX	Journal of Institute of Croatia Language and Linguistic	✓	✓	✓	✓	✓	5	Acceptance
21	Verryna Rosita Sari & Nina Hayuning tyas (2024)	Indonesia	QL	Critical Review of English-Arabic World Journal	✓	✓	✓	✓	✓	5	Acceptance
22	Kefalis, Skordouli s & Drigas (2025)	Greece	MX	Algorithmic and Procedural Learning	✓	✓	✓	✓	✓	5	Acceptance
23	Kohnke & Zaugg (2025)	USA	MX	Education Sciences	✓	✓	✓	✓	✓	5	Acceptance
24	Getaneh Berta & Aster Mulat (2024)	Ethiopia	QL	English Language, Literature & Culture	✓	✓	✓	✓	✓	5	Acceptance
25	Zalva Arwanda et al. (2025)	Indonesia	MX	Jurnal Perkembang an Ilmiah Multidisiplin	✓	✓	✓	✓	✓	5	Acceptance
26	Pangand aman et al. (2024)	Filipina	MX	Cuest.fisioter	✓	✓	✓	✓	✓	5	Acceptance
27	Aleksieva (2025)	Bulgaria	MX	Education Sciences	✓	✓	✓	✓	✓	5	Acceptance
28	Syifa Nurhikm ah Lestari et al. (2025)	Indonesia	MX	Integrative Perspectives of Social and Science Journal	✓	✓	✓	✓	✓	5	Acceptance
29	Taufik Arochma n et al. (2024)	Indonesia	QL	Theory and Practice in Language Studies	✓	✓	✓	✓	✓	5	Acceptance

30	Şule Bıyık Bayram (2024)	Turkey	QN	Mediterrane an Nursing and Midwifery	✓	✓	✓	✓	✓	5	Acceptance
31	Felcida & Parames waran (2024)	India	QN	Revue de Traduction et Langues	✓	✓	✓	✓	✓	5	Acceptance
32	Alexandr a Okada (2025)	United Kingdom	QL	SpringerBrief s in Advanced Information and Knowledge Processing	✓	✓	✓	✓	✓	5	Acceptance
33	Rozaini Ahmad et al. (2022)	Malaysia	QN	International Journal of Learning, Teaching and Educational Research	✓	✓	✓	✓	✓	5	Acceptance
34	Na Ta et al. (2023)	Malaysia / China	QN	World Journal of English Language	✓	✓	✓	✓	✓	5	Acceptance
35	Avita Rath (2025)	Malaysia	QL	Frontiers in Medicine	✓	✓	✓	✓	✓	5	Acceptance
36	Theodori o et al. (2024)	South Africa	QL	Education and Information Technologies	✓	✓	✓	✓	✓	5	Acceptance
37	Fang et al. (2024)	UAE / Russia	QN	BMC Psychology	✓	✓	✓	✓	✓	5	Acceptance

QA = Quality Assessment, QL = Qualitative, QN = Quantitative, MX = Mixed RESEARCH FINDINGS

Background of the Study: Chosen Research Area

Publication Year of Articles

In 2023, there were 9 articles published, and in 2024, there were 16. This indicates a growing interest and focus on the topics studied, particularly within the context of educational technology and the use of visual aids like digital mind maps. 2024 was the most active year, demonstrating the maturity of this research area and the emergence of various relevant studies. Although 2025 is not yet complete, there are already 10 articles published, indicating that research is still active and evolving in the field of educational innovation and learning technology.

Table 4
Number of articles by year

Year	Number of articles
2021	2
2022	2
2023	7
2024	16
2025	10

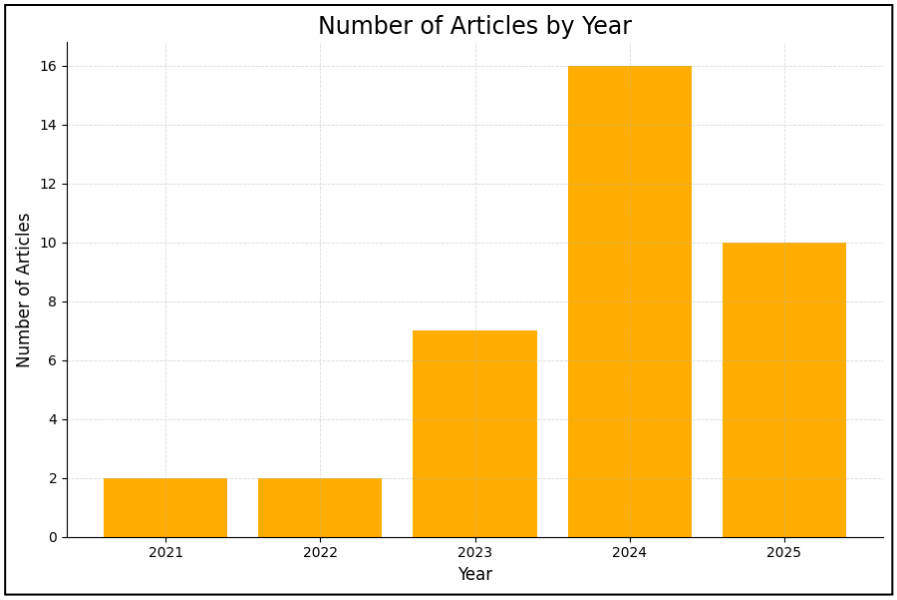


Figure 2: The graph above illustrates the distribution of articles based on their year of publication, according to the 37 articles analyzed.

Design of Studies in Journal Articles

37 articles were analyzed in terms of study design. The analysis revealed that the majority of studies used a quantitative approach, with 23 articles followed by mixed methods and qualitative studies. This finding highlights the researchers' preference for quantitative methods in evaluating the effectiveness of learning interventions, while mixed and qualitative methods are used in studies that require in-depth exploration of perceptions and experiences.

Table 5
Numbers according to study type

Category of Study	**Number of articles**	**Authors**
Quantitative	23	Shahida Munir et al., Sana Khan et al., Nyagblormase et al., Dennis Fung & Tim Liang, Nurhikmah Hasyim et al., Min-Chi Chiu & Gwo-Jen Hwang, Rafidah Abd Karim & Ramlee Mustapha, Yinghui Shi et al., Menglin Fang et al., Rais & Zulfa, Hasbollah et al., Yasir et al., Esther Emma & Ruhizan, Shalma Hudi Cahyani & Agustina T.A.H., Wan Nor Syazwani et al., Şule Bıyık Bayram, Felcida & Parameswaran, Rozaini Ahmad et al., Na Ta et al., Min-Chi Chiu & Gwo-Jen Hwang, Fang et al.
Qualitative	9	Debbag et al., Parinduri, Ramadhani et al., Verryna Rosita Sari & Nina Hayuningtyas, Getaneh Berta & Aster Mulat, Taufik Arochman et al., Alexandra Okada, Avita Rath, Theodorio et al.
Mixed Methods	8	Nita Agustina et al., Eglė Selevičienė, Kefalis, Skordoulis & Drigas, Kohnke & Zaugg, Zalva
		Arwanda et al., Pangandaman et al., Aleksieva, Syifa Nurhikmah Lestari et al.

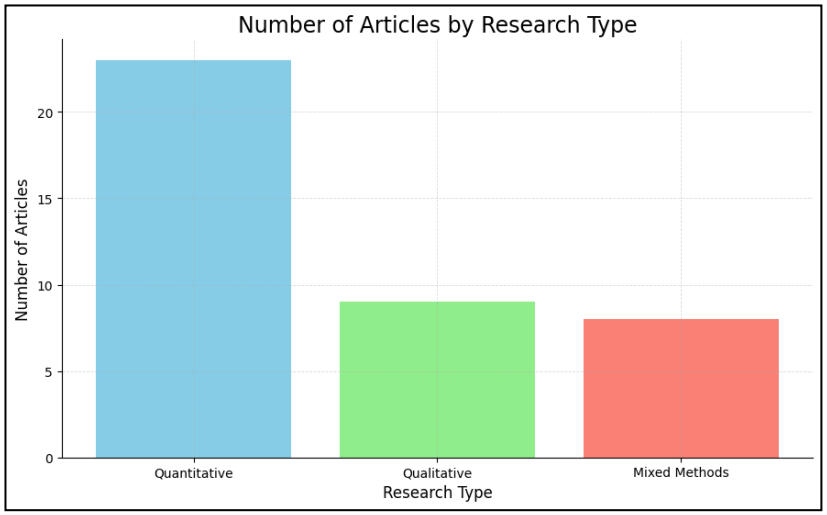


Figure 3: Number of articles by study type

Area of Focus

Based on an analysis of 37 articles reviewed, the majority of studies were conducted in countries in Asia, such as Indonesia and Malaysia, which contributed 10 and 8 articles respectively. Countries such as Pakistan, Turkey, and the UAE contributed 2 articles each, while Bulgaria, China, Ethiopia, the Philippines, Ghana, Greece, Hong Kong, India, Lithuania, South Africa, the USA, Taiwan, and the United Kingdom each contributed 1 article.

This distribution highlights the geographical diversity in research on the effectiveness of digital mind maps in education. It also reveals a significant concentration of studies in developing countries that are actively integrating technology into their education systems.

Table 6

Numbers by Country

Country	**Number of articles**
Bulgaria	1
China	1
Ethiopia	1
Filipina	1
Ghana	1
Greece	1
Hong Kong	1
India	1
Indonesia	10
Lithuania	1
Malaysia	8
Pakistan	2
South Africa	1
Taiwan	1
Turkey	2
UAE	2
USA	1
United Kingdom	1

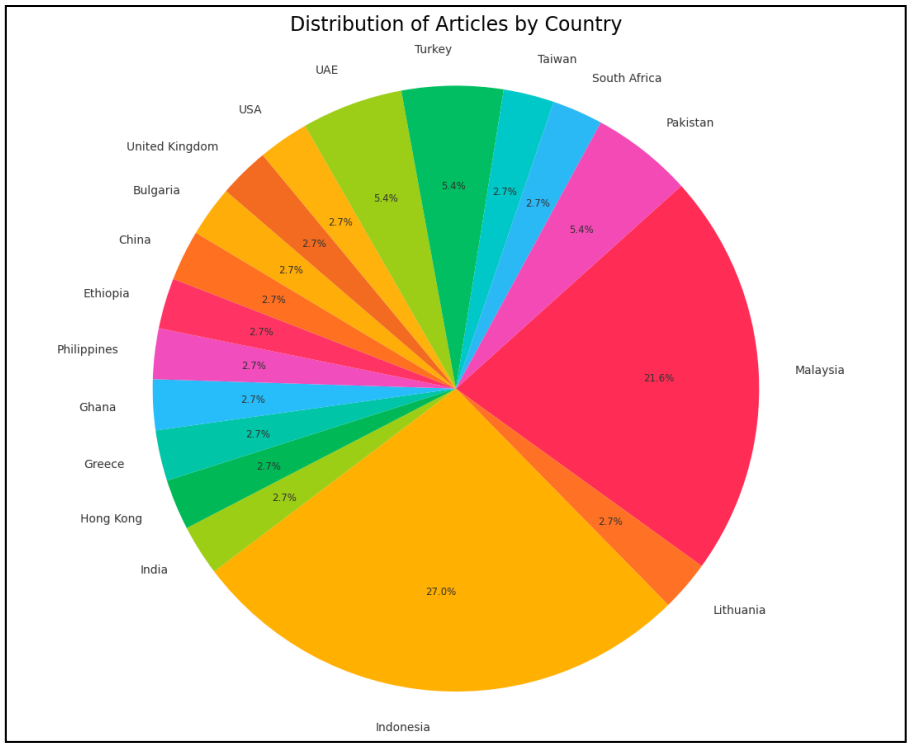


Figure 4: The chart above shows the distribution of articles by country of publication, based on the 37 articles analyzed

Publication Journal Analysis

The analysis of the journals reveals that the studied articles were published in various international journals related to the fields of education and psychology. "Education and Information Technologies" and "BMC Psychology and Education Sciences" are two journals and other journals contributed one article each. This diversity of journals reflects the research conducted by researchers from diverse backgrounds on the topic of the use of mind maps and digital tools in education. It also indicates that research in this field has received wide attention not only in terms of pedagogy but also from the perspectives of psychology and technology.

Table 7
Number of articles per journal

Journal	**Authors**	**No. of Arcticles**
Asia Pacific Education Review	Yinghui Shi et al.	1
BMC Psychology	Menglin Fang et al.; Fang et al.	2
Child Education Journal	Ramadhani et al.	1
Cogent Education	Nurhikmah Hasyim et al.	1
Algorithmic and Procedural Learning	Kefalis, Skordoulis & Drigas	1
Critical Review of English-Arabic World Journal	Verryna Rosita Sari & Nina Hayuningtyas	1
Cuestiones de Fisioterapia	Pangandaman et al.	1
Education Sciences	Kohnke & Zaugg; Aleksieva	2
Education and Information Technologies	Theodorio et al.; Min-Chi Chiu & Gwo-Jen Hwang	2

English Language, Literature & Culture	Getaneh Berta & Aster Mulat	1
Frontiers in Medicine	Avita Rath	1
Informatics in Education	Debbag et al.	1
Innovative Teaching and Learning Journal	Yasir et al.	1
Integrative Perspectives of Social and Science Journal	Syifa Nurhikmah Lestari et al.	1
International Journal of Learning, Teaching and Educational Research	Rozaini Ahmad et al.	1
International Journal of Science and Mathematics Education	Dennis Fung & Tim Liang	1
Journal of Integrated Elementary Education	Nita Agustina et al.	1
Journal of Social Science Utilizing Technology	Rais & Zulfa	1
Journal of Technical Education and Training	Rafidah Abd Karim & Ramlee Mustapha	1
Journal on Education	Shalma Hudi Cahyani & Agustina T.A.H.	1
Jurnal Inovasi Pendidikan Sains dan Terapan	Parinduri	1
Jurnal Perkembangan Ilmiah Multidisiplin	Zalva Arwanda et al.	1
Malaysian Journal of Social Sciences and Humanities (MJSSH)	Esther Emma & Ruhizan	1
Mediterranean Nursing and Midwifery	Sulw Biyik Bayram	1
Journal of the Institute of Croatia Language and Linguistic	Egle Seleviciene	1
Regional TVET Conference - ReTVET	Hasbollah et al.	1
Research Journal for Societal Issues	Shahida Munir et al.	1
Revue de Traduction et Langues	Felcida & Parameswaran	1
Seminar Pembelajaran Sepanjang Hayat (SPSH2024)	Wan Nor Syazwani et al.	1
SpringerBriefs in Advanced Information and Knowledge Processing	Alexandra Okada	1
Studies in Learning and Teaching	Nyagblormase et al.	1
Theory and Practice in Language Studies	Taufik Arochman et al.	1
Tidak pasti	Sana Khan et al.	1
World Journal of English Language	Na Ta et al.	1

RQ1: What is the impact of using digital mind maps on students in science learning?

The use of digital mind maps in science learning has been found to have a positive impact on students' understanding and mastery of concepts. Findings from studies by Shahida Munir et al. and Sana Khan et al. (2024) show that mind maps help students to understand science concepts more clearly through the visual and organized arrangement of information. This method has also been shown to improve students' long-term memory due to visual repetition and the hierarchical structure of information, as reported in the studies by Debbag et al. (2021) and Min-Chi Chiu and Gwo-Jen Hwang (2024). In addition, experimental studies such as those by Menglin Fang et al. (2024) and Yasir et al. (2023) have shown that the use of digital

mind maps significantly improves students' academic achievement compared to traditional methods.

The use of digital mind maps is also seen to stimulate students' motivation and interest in learning science. This is supported by the findings of Nurhikmah Hasyim et al. (2024) and Hasbollah et al. (2023), which found that the use of visual and interactive elements in mind maps makes the learning process more enjoyable and engaging, thereby increasing students' active participation in the classroom. In addition, this approach also fosters students' critical and creative skills, as presented by Rais and Zulfa (2024) and Ramadhani et al (2023), where students are encouraged to analyze and connect science concepts in their own way.

A meta-analysis by Yinghui Shi et al. (2023) also supports the fact that digital mind maps help students to build more comprehensive relationships between concepts, contributing to a deeper understanding of science topics. From the perspective of Rozaini et al. (2022) and Esther Emma and Ruhaizan (2024), digital mind maps make it easier for teachers to plan lessons systematically and deliver content more effectively. Furthermore, a study by Avita Rath and Nita Agustina et al. (2025) confirms the effectiveness of digital mind maps for students because they are flexible and easy to adapt.

In conclusion, the findings from these 37 articles show that digital mind maps not only effectively improve students' understanding, memory, and achievement in science, but also stimulate their interest, motivation, and engagement in learning science. This approach is in line with the needs of 21st-century learning and is very suitable for implementation in the context of primary education in Malaysia.

RQ2: Do students perceive digital mind maps as effective tools for learning science concepts?
Student perceptions of using digital mind maps in learning science concepts consistently show a very positive trend across various countries. Students report that digital mind maps facilitate understanding of complex concepts through visual, organized, and hierarchical presentation of information. In Malaysia, studies by Shahida Munir et al. (2023) and Rozaini Ahmad et al. (2022) found that students found it easier to understand the subject matter and enjoyed a more engaging learning experience. The use of visual elements like color and icons makes the content more memorable.

Findings from Rais and Zulfa (2024), Ramadhani et al. (2023), and Shalma Hudi Cahyan and Agustina (2024) also confirm that students consider digital mind maps as an enjoyable and effective learning method. They also state that creating their own digital mind maps helps build confidence and provides control over the learning process.

Min-Chi Chiu and Gwo-Jen Hwanh (2024) found that students have a very positive perception of using digital mind maps for comprehensive and in-depth learning of science concepts.

Based on the literature review of Theodorio et al. (2024), students value this visual approach because it promotes active engagement and helps them to organize information more clearly.

According to Yinghui Shi et al. (2023), students appreciate the ability of digital mind maps to enhance focus, reduce cognitive load, and make learning more structured. Felcida and Parameswaran (2024) found that students felt more confident in answering questions and mastering concepts when learning involved interactive digital mind maps.

In a study by Alexandra Okada (2025), students showed a high degree of openness to using digital mind maps. Students who participated in the study stated that using digital mind maps allowed them to explore a variety of information sources, think more systematically, and understand concepts more deeply. Digital mind maps also provide students with the opportunity to develop self-reflection and critical thinking skills in their learning.

In conclusion, student perceptions from various countries show that digital mind maps are very effective in supporting student understanding, memory, and engagement in learning science concepts. This method not only makes learning more engaging and meaningful but also aligns with the principles of 21st-century learning, which emphasize the integration of technology, creativity, and critical thinking in the classroom.

Disccusion of Research Findings

Overall, the findings from the 37 reviewed articles fully support the assertion that the use of digital mind maps in learning science concepts is an effective and high-impact pedagogical approach. This method not only helps improve students' understanding, memory, and achievement but also stimulates their motivation, engagement, and 21st-century skills. This is supported by the research of Min-Chi Chiu and Gwo-Jen Hwang (2024), which found that the use of digital mind maps enhances students' comprehensive understanding of science topics, and by the research of Alexandra Okada (2025), which shows that students are more motivated and confident when actively involved in creating digital mind maps. Therefore, this approach is highly appropriate for use in science teaching in primary schools, particularly in supporting the learning needs of low-achieving students (TP1 and TP2) who require visual and structured interventions in their learning process.

Conceptual Framework: The Effectiveness of Digital Mind Maps in Improving Student Understanding of Scientific Concepts in Learning.

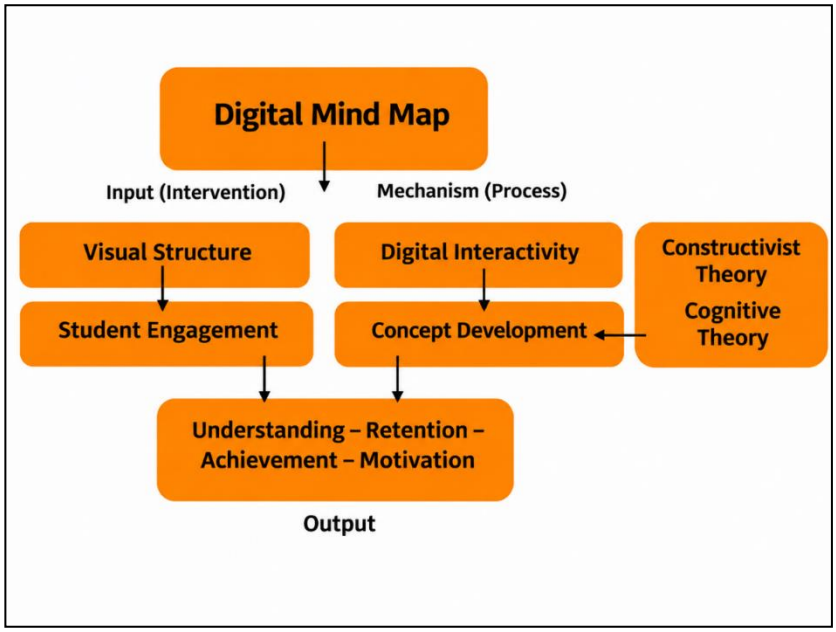


Figure 5: Conceptual Framework: The Effectiveness of Digital Mind Maps in Enhancing Students' Understanding of Science Concepts in Learning

Implication of the Study

This study, based on an analysis of 37 articles on the use of digital mind maps in learning science concepts, has yielded several important implications for teaching practices, curriculum design, and educational research. These implications provide valuable guidance to teachers, policymakers, and researchers in enhancing science learning.

The study findings indicate that the use of digital mind maps helps to improve student understanding, memory retention, and achievement. Teachers can use this approach to deliver content in a more systematic and engaging way. Therefore, teachers should integrate digital mind maps as one of the main teaching strategies in science.

The effectiveness of using digital mind maps in teaching and learning also highlights the need to enhance teachers' pedagogical skills in designing and facilitating digital mind map activities. These skills include the ability to use digital tools such as Canva and Padlet, and to guide students in creating their own concept maps. Therefore, ongoing professional development programs should emphasize pedagogical and visual information presentation strategies.

The study findings also suggest that the current curriculum should emphasize visual and digital learning strategies such as mind maps. This aligns with the objectives of the Malaysian Education Blueprint (2013-2025), which emphasizes the development of 21st-century skills among students. By making the use of digital mind maps a key component of the science curriculum, students will have the opportunity to develop a deeper and more reflective understanding of the subject matter.

Finally, this study opens up avenues for further research in the field of digital education and visual pedagogy. Action research can be conducted to develop specific modules on the use of digital mind maps with other technologies such as AI to enhance student learning and teaching effectiveness.

Research Gaps

While previous studies have highlighted the various benefits of using digital mind maps in learning, there are still significant research gaps that need further exploration, particularly in the context of primary education in Malaysia.

Much of the existing research has been conducted outside or within the secondary and higher education settings. Local studies focused on primary-level students, such as those examining mastery levels 1 and 2 in science, are limited. These students require more visual and structured pedagogical approaches, but interventions specifically designed for them are still lacking.

Many studies also have a short-term focus. Long-term studies that track the impact of digital mind maps on the cognitive development and academic achievement of students over time are scarce. Such studies are crucial for assessing the long-term effects and the true potential of this method in building a strong foundation in science.

Many studies focus primarily on student perceptions, but they often neglect the perceptions of teachers, school administrators, and parents. Understanding these perspectives is essential for gaining widespread support for the systematic and effective implementation of digital pedagogy.

These identified gaps highlight the need for further research. Future research should delve into these areas in detail to strengthen the implementation of this approach in the Malaysian education system, particularly for primary school students.

Suggestions for Further Research

Based on the findings of this study, several further research suggestions are proposed to strengthen the implementation and investigation of the use of digital mind maps in science learning. It is suggested that future studies investigate the effectiveness of digital mind maps based on different student learning levels (TP 1 to TP 6) in more detail, to tailor intervention strategies to the specific needs of different students.

It is recommended that longitudinal studies be conducted to assess the impact of digital mind maps on long-term memory and continuous improvement in student achievement from one level to another.

In addition to studying student perceptions, further research could focus on the perceptions of teachers and parents regarding the use of digital mind maps. This is important to gain comprehensive support for the implementation of technology-based teaching and learning in schools.

Conclusion

This study has demonstrated that the use of digital mind maps is an effective pedagogical approach, particularly in the context of science learning at the primary school level. Analysis of 37 articles revealed that this approach has a comprehensive impact on improving students' understanding, memory, and academic achievement. The visual structure and hierarchy in digital mind maps help students to organize information more systematically, while also facilitating the connection of science concepts they are learning.

Furthermore, this approach has also been found to stimulate students' interest and motivation in learning. Interactive and user-friendly digital mind maps enhance active student engagement in the classroom, while also helping to build confidence and self-learning skills. Student perceptions of this method are very positive, as shown in various studies both domestically and internationally.

From a teaching perspective, digital mind maps also help teachers to plan and deliver lessons in a structured and engaging way. This aligns with the needs of 21st-century education, which

emphasizes the integration of technology, high-order thinking skills (HOTS), and student-centered learning.

The use of digital mind maps in learning science concepts not only supports the achievement of curriculum objectives but also provides ample opportunities for students to develop their cognitive, emotional, and social potential. Therefore, this approach should be widely and systematically implemented, particularly among primary school students at levels 1 and 2, which require visual support and structure in building concept understanding. This study also suggests that teacher training and curriculum improvements are needed to support the effective use of mind maps.

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