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Fostering Learning Base Digital Mind Maps To Improve Student's Problem-Solving Skills in Senior High Schools

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ABSTRACT

Problem-solving skills are essential for fostering creativity and enhancing students' decision-making abilities. One promising strategy to develop these skills is through active learning using digital mind maps, which help students visually structure and connect information. This study employed a quasi-experimental, non-equivalent control group design to assess the effectiveness of digital mind maps in enhancing problem-solving skills. A total of 100 students were selected through cluster sampling. The experimental group engaged in active learning using digital mind maps, while the control group followed a traditional learning approach. Data were collected using standardized test instruments, with validity evaluated through the Aiken index and reliability measured using Cronbach's alpha. Quantitative descriptive analysis was used to interpret the results. The findings showed a statistically significant improvement in problem-solving skills among students in the experimental group compared to the control group (Sig = 0.00 < α), indicating the effectiveness of digital mind maps in facilitating learning. The use of digital mind maps within an active learning framework significantly enhances students' ability to solve problems. This method not only supports the development of critical thinking and decision-making skills but also promotes a shift in how students process and engage with information in science education. Digital mind maps are an effective active learning tool for improving students' problem-solving abilities and have meaningful implications for educational practices.

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1. INTRODUCTION

In the 21st century, digital competence has become a critical component of educational development, particularly through the integration of tools like digital mind mapping. These tools not only enhance students' technological literacy—by encouraging the use of software, applications, and cloud-based platforms—but also support idea organization and knowledge sharing. Digital mind maps foster active learning environments that cultivate critical thinking and problem-solving, requiring students to explore concepts more deeply and identify meaningful connections.

Modern education must equip students with the skills and adaptability needed to meet global demands. According to Wahyu and Sri (2019), 21st-century learning emphasizes the development of abilities essential for global competitiveness. This includes creative thinking, real-world knowledge application, technological proficiency, and strong communication and collaboration skills (Dakhi et al., 2020; Fong, Sidhu, & Fook, 2014). In the context of the Fourth Industrial Revolution, the rapid advancement of science and technology requires education systems to evolve continuously. As Hermino and Arifin (2020) highlight, educational innovation is vital to align teaching practices with ongoing technological progress and to improve learning outcomes.

However, without the support of digital mind mapping, students often struggle to structure their thoughts and ideas when solving problems. They may gather information but fail to organize it logically, leading to inefficient problem-solving processes. This fragmented thinking hinders their ability to identify relevant solutions or construct coherent steps toward resolution. Moreover, without visual tools to link concepts, students tend to think linearly, relying on familiar methods rather than exploring diverse, creative alternatives (Chang, Chiu, & Huang, 2019).

Problem-solving skills are crucial in the learning process and can be incorporated across various educational levels and disciplines. These skills require active engagement from learners during discussions. As such, the teacher's role is primarily to facilitate learning (Osman, Duffy, Chang, and Lee, 2011). However, many teachers present the subject matter without promoting student interaction or encouraging active participation, limiting opportunities for students to analyze and engage with the topics being discussed. Furthermore, problem-solving skills are essential for students in navigating the challenges of the 21st century. Effective problem-solving relies on scientific reasoning to draw accurate conclusions (Yanto et al., 2019). Therefore, students must be able to actively apply 21st-century skills, demonstrate initiative, and collaborate effectively (Ahmad et al., 2016). In math education, the process is expected to foster a scientific understanding, allowing students to deepen their thinking and enhance their problem-solving abilities.

According to a preliminary study by Sagita and Sani (2019), improving student learning outcomes, which reflects better education quality, can be achieved by adopting an appropriate learning model. One such model, which aligns with the scientific approach and promotes problem-solving, is the digital mind map-based learning. Jankowska et al. (2019) note that many factors influence the development of thinking skills. Teachers, as educators, must foster students' collaborative abilities by encouraging them to become problem solvers. Hence, math instruction in schools should focus on problem-solving activities. The importance of problem-solving skills has been recognized by various researchers (Afriansyah, 2016; Yusri, 2013; Dewi & Minarti, 2018). Given that future challenges require innovative solutions, problem-solving is crucial in science education (Docktor et al., 2015; Mason & Singh, 2016). However, high school students' problem-solving abilities remain inadequate (Azizah et al., 2015). This study explores the use of digital mind map-based learning to enhance problem-solving skills.

To address this learning challenge, students can be assigned mind-mapping tasks. Mind maps are useful for helping students organize their prior knowledge. These maps have a radial structure, allowing concepts to be visually represented in branches, often highlighted with colors. They are arranged hierarchically, with main concepts at the center and supporting details placed in subsequent levels (Stokhof et al., 2020). Mind maps can also be created using digital tools, known as digital mind maps (DMM) (Iao-qiang et al., 2015).

The use of digital mind maps in active learning has a wide range of positive impacts, from increasing student engagement and creativity to developing important skills such as collaboration, critical thinking, and digital literacy. These implications suggest that digital mind maps are not just a tool, but also a method that can enrich the learning experience and prepare students for future challenges. Digital-based mind map media effectively conveys information through auditory, visual, and other visual elements (Buran & Filyukov, 2015; Susilawati et al., 2017). Mind maps enable students to engage both hemispheres of the brain simultaneously, facilitating the expression of ideas more easily

(Chang, Chiu, & Huang, 2019). A mind map is a creative, efficient way of taking notes that visually organizes students' thoughts. The use of digital mind map tools makes it easier for students to take notes using words, colors, lines, and symbols, enhancing their ability to retain and process assignments or materials provided by the teacher (Liu et al., 2018). Other studies have shown that the guided inquiry learning model, supported by mind map media, has a positive impact on creative thinking skills (Pratama et al., 2020). Additionally, research indicates that the Student Facilitator and Explaining (SFAE) learning model, which incorporates mind map media, boosts students' learning creativity (Dewi et al., 2020).

The use of learning media is intended to support students in understanding and mastering educational content (Hendrick et al., 2019). As such, the media should be designed to be as engaging as possible. One innovative tool that can be utilized is digital-based mind map media. Mind maps are a widely recognized tool for stimulating and organizing higher-order thinking concepts during the learning process (Susilawati et al., 2017). These mind maps assist both teachers and students by summarizing essential learning content into multiple mind map sheets, making it easier for students to study and retain information (Setiawan & Wiedarti, 2020). A mind map integrates concepts from both hemispheres of the brain—logical, procedural, verbal, and numerical elements from the left brain, alongside visual elements like pictures, imagination, color, and spatial arrangements from the right brain. It is a thinking tool that combines words, images, symbols, and other methods of information representation. Mind map applications can enhance students' ability to store information and improve their understanding and learning efficiency. Typically, mind maps consist of a hierarchical structure of categories and concepts, often depicted using words, phrases, colors, or sketches (Setiawan & Wiedarti, 2020). The educational curriculum of the 21st century is focused on producing a productive, creative, innovative, and effective generation, integrating knowledge, skills, and attitudes essential for life (Pratama et al., 2020).

The use of technology in education plays a crucial role, and DMMs leverage applications that help connect concepts with lines, visualizing and classifying ideas (Iao-qiang et al., 2015). Integrating DMM into learning is anticipated to enhance students' active participation and collaborative learning in the classroom (Hidayati et al., 2019). This study aims to examine the impact of digital mind map-based learning on improving problem-solving skills. Based on the background and issues outlined above, this research centers on the use of digital mind map-based learning to enhance students' problem-solving abilities. To effectively implement this approach, teachers need to have a solid understanding of the science content and be capable of conveying these concepts using technology. Therefore, the research question is: How can digital mind map-based learning be used to improve students' problem-solving skills?

2. METHOD

This study aims to examine the effectiveness of digital mind map-based learning in enhancing students' problem-solving skills. A quasi-experimental design with a non-equivalent control group was employed to compare the improvement in problem-solving abilities between students exposed to digital mind map-based learning and those taught using a conventional method.

In the control group, students followed a traditional instructional model, which included classroom discussions led by the lecturer, followed by a direct explanation of the material. The lecturer maintained a dominant role, delivering content primarily through lectures.

In contrast, the experimental group participated in a digital mind map (DMM)-based learning process, structured as follows:

1. Students began by creating digital mind maps to activate prior knowledge and link it with new concepts.
2. Real-world problems were then introduced to contextualize learning.

3. During problem-solving activities, students revised and expanded their mind maps to incorporate insights gained.
4. They prepared reports and presented their findings.
5. Finally, students reflected on and evaluated their problem-solving process.

2.1 Participants

The study involved 100 eleventh-grade students from MAN 1 Bengkulu City, divided into two groups: 50 in the experimental group and 50 in the control group. This school was selected for its access to digital learning facilities and infrastructure. A cluster sampling technique was used, as it is cost-effective and time-efficient, particularly for studies with large populations. In this case, intact classes were used as clusters, reducing the logistical burden on researchers (Sugiyono, 2015). Ethical approval and participant consent were obtained prior to data collection.

2.2 Instruments and Data Collection

Data on students' problem-solving skills were collected using essay-based tests administered before and after the intervention (pretest and posttest). Test items were developed based on specific indicators aligned with each component of problem-solving, and responses were scored using a 0–5 rating scale:

- 0: No correct answer
- 1: Correctly identifies given quantities
- 2: Correctly formulates the problem
- 3: Selects an appropriate and correct formula
- 4: Applies given quantities correctly in the formula
- 5: Provides accurate calculation and draws a correct conclusion

The test grid used to evaluate problem-solving skills is presented in Table 1.

Table 1. Problem-Solving Ability Test Grid

Aspects	Indicators
Defining Problems	a. Determining the types of problem
	b. Mentioning all the information provided
	c. Completing the problem sketch
	d. Stating the final goals that must be met from the existing problems
Exploring Problems	a. Describing the condition of the objects
	b. Describing free diagrams
	c. Making assumptions that must be met
Solving Problems using a well-planned procedure	a. Describing given information
	b. Specifying the information to be determined
	c. Constructing the structure of equations from theories, principles, and the appropriate physics laws
	d. Producing the right solutions
Evaluating and Reflecting on Problem Solving	a. Making conclusions based on solutions completed with appropriate theories
	b. Evaluating statements based on the theories, principles, and laws of physics

The research instruments were validated by two educational experts, confirming their content validity. To assess the validity of the items, the expert agreement was analyzed using Aiken's V index, which measures the extent of consensus among raters. Instrument reliability was evaluated using Cronbach's alpha coefficient, yielding a value of 0.89 for the problem-solving test. This score indicates high reliability, based on the categorization proposed by Taber (2018). The results of the validity and reliability analysis are presented in Table 2 below.

Table 2. The results of the Aiken Index Coefficient of Instrument Validity

Instruments	V	Validity
Problem-solving skills	0.81	Valid

2.3 Data Analysis

The data were analyzed using an independent sample t-test at a significance level of 0.05 to examine the effect of digital mind map-based learning on students' problem-solving skills. A p-value less than 0.05 indicates a statistically significant difference between groups, suggesting that the intervention had a measurable impact.

Prior to hypothesis testing, assumptions of normality and homogeneity were evaluated. Normality was assessed using the One-Sample Kolmogorov–Smirnov Test, and homogeneity of variance was tested with Levene's Test. After confirming that the data met these assumptions, the independent sample t-test was conducted to determine whether there were significant differences in the mean problem-solving scores between the experimental and control groups.

3. FINDINGS AND DISCUSSION

3.1 Findings

The effectiveness of the digital mind map-based learning model was evaluated based on its impact on enhancing students' problem-solving skills. The model is deemed effective if it leads to a statistically significant improvement in these skills. Preliminary analyses included tests of normality and homogeneity to ensure the data met the assumptions required for parametric testing.

Normality was assessed using the Kolmogorov–Smirnov test, which yielded significance values of 0.251 for the experimental group and 0.322 for the control group—both above the threshold of 0.05—indicating that the data are normally distributed. Homogeneity of variance was tested using Levene's test, resulting in a significance value of 0.352, which also exceeds 0.05, confirming homogeneous variance across the groups.

To determine the effectiveness of the intervention, an independent sample t-test was conducted at a 95% confidence level. A p-value below 0.05 was considered indicative of a significant difference in the mean scores between groups. The results demonstrate that students taught using the digital mind map-based model outperformed those in the traditional learning group. Specifically, the experimental group's average score increased from 12.74 (pretest) to 81.34 (posttest), while the control group improved from 11.54 to 61.78 (see Table 3). These findings indicate that the digital mind map-based learning model significantly enhances students' problem-solving abilities compared to conventional instruction.

Table 3. Description of problem-solving skills

Variable	Stat.	Learning based digital mind maps				Conventional Teaching			
		n	Pre-test	Post-test	N<G>	n	Pre-test	Post-test	N<G>
problem-solving skills	$\ddot{x}$	50	12.74	81.38	.81	50	11.54	61.78	.28
	%		25	100			25	75	
	s		1.46	1.97			1.45	1.82	

To evaluate the effectiveness of digital mind map-based learning on students' problem-solving skills, an independent sample t-test was conducted to compare the pretest and posttest scores of the experimental and control groups. This statistical test was used to determine whether there were significant differences in the mean scores between the two groups before and after the intervention.

Table 4 presents the results of the t-test, including the t-values and significance levels (Asymp. Sig. 2-tailed) for both the pretest and posttest comparisons.

Table 4. The result of the independent sample t- test

Group	t	Asymp. Sig. (2-Tailed)
Pretest Experiment Control	.711	.015
Posttest Experiment Control	15.213	.000

The table above indicates that the p-value falls below the 0.05 threshold, leading to the rejection of the null hypothesis (H_0). This outcome confirms a statistically significant difference in problem-solving abilities between the experimental and control groups. The results highlight a noticeable disparity in the average scores, demonstrating that the digital mind map-based learning approach used in the experimental group is more effective in enhancing students' problem-solving skills compared to the traditional instructional method applied in the control group.

3.2 Discussion

The findings of this study indicate that the use of digital mind map-based learning in the experimental group is significantly more effective in enhancing students' problem-solving skills compared to the conventional instructional model used in the control group. The statistical analysis yielded a significance value of 0.00 ($p < 0.05$), confirming a notable difference in learning outcomes between the two groups. This result underscores the effectiveness of digital mind maps as a pedagogical tool that can support structured thinking and systematic problem-solving in the classroom (Muhammad et al., 2018). The success of this approach is supported by previous research, which has shown that electronic mind mapping enhances a range of academic skills, including critical reading, English writing, content organization, motivation, and higher-order thinking such as reasoning and critical analysis (Siriphanic & Laohawiriyanon, 2010).

Despite their benefits, several challenges can hinder the effective implementation of digital mind maps. One common issue is limited visualization options—traditional, hand-drawn mind maps often allow for more creative freedom in layout and design, which can make them easier to interpret. In contrast, digital platforms may offer more rigid templates, potentially constraining creativity and user expression. Additionally, not all digital mind-mapping tools provide features aligned with users' needs, such as real-time collaboration, integration with other software, or flexible map structuring. Users may also face difficulties organizing complex or interconnected ideas on a digital interface. A lack of experience with or understanding of the application can further impede optimal use, especially for students or educators unfamiliar with digital tools, creating a learning curve that must be overcome for effective implementation.

Implications of implementing digital mind maps include the following: Digital mind maps allow for quick creation, editing, and sharing of mind maps. This can increase efficiency in planning projects or mapping ideas, which in turn increases productivity. Many digital applications support real-time collaboration, allowing teams to work together, provide input, and change mind maps simultaneously. This is especially useful for brainstorming or planning strategies together.

Several studies have demonstrated that electronic mind mapping (E-Mind Mapping) is more effective than conventional teaching methods. For instance, Mohaidat (2018) found that students who engaged in electronic mind mapping showed higher levels of comprehension compared to those in the control group taught using traditional techniques. The experimental group also exhibited improved reading comprehension, attributed to the benefits of using digital mind maps. Mohaidat emphasized that incorporating digital mind maps into the learning environment can significantly enhance both teaching and learning by catering to the diverse learning preferences of students.

Supporting this, Dongoran et al. (2019) highlighted that structured methods for organizing creative thoughts can enhance problem-solving abilities. Such instructional strategies can be geared toward improving the learning experience, developing creativity, and fostering students’ Higher Order Thinking Skills (HOTS), as also noted by Dewi et al. (2019).

Furthermore, online discussion forums are recognized as effective platforms for improving communication and the overall quality of interaction between teachers and students (Tikno, 2017). It regarded electronic mind mapping as an active learning strategy that enhances memory retention, idea generation, and information recall. Since it mirrors natural cognitive processes by stimulating both brain hemispheres, it organizes knowledge in a way that supports better understanding compared to linear note-taking. Digital mind maps, often created using specialized software, resemble free-flowing creative diagrams. They use central nodes with branches extending outward, incorporating words, symbols, and colors to visually represent interconnected ideas. This method requires spontaneous and creative thinking during the construction process.

Stankovic Besic, Papic, and Aleksic (2011) also noted that electronic mind maps are more engaging, faster to create, and more professionally structured than traditional formats. Hidayati et al. (2020) similarly concluded that digital mind mapping techniques are highly effective in enhancing reading comprehension.

Evidence from this research further supports that using digital mind maps as an instructional tool can effectively improve students' problem-solving skills. Both teachers and students followed a well-defined learning procedure, which played a crucial role in the success of the instructional model. According to Hu (2017), creative and integrative learning frameworks encourage active collaboration between students and teachers. In such environments, teachers facilitate student development by guiding and supporting their involvement in problem-solving tasks.

Various studies confirm that the integration of digital mind maps in education yields benefits not only for students and teachers but also for the broader educational community. These tools are particularly valuable for brainstorming, allowing learners to capture ideas freely before organizing and ranking them. Compared to conventional outlines, mind maps offer a more dynamic way of structuring ideas. Murley (2007) explained that the radial design of a mind map places the main concept at the center, with related subtopics branching outward. This layout helps learners maintain a holistic view and better understand the connections between ideas.

Research by Purwoko (2013) shows that digital mind mapping activates students' cognitive processes, helps them overcome mental barriers, clarifies core concepts, and enables them to see the relationships between different pieces of information. Similarly, Al-Otaibi (2016) and Hariyadi, Corebima, and Ibrohim (2018) found that mind maps support reading comprehension by allowing students to structure and compare concepts effectively. Moreover, creating colorful and personalized mind maps can inspire creativity, strengthen memory retention, and increase student motivation and engagement. Overall, digital mind maps can be a powerful tool for teachers seeking to foster creativity, improve memory, and promote an active and enjoyable learning environment.

4. CONCLUSION

This study concludes that digital mind map-based learning is an effective and efficient strategy for enhancing students’ problem-solving skills, as evidenced by a significant difference in mean scores between the experimental and control groups. Students taught using digital mind maps outperformed those in traditional learning environments, demonstrating the model's potential to support deeper cognitive engagement in mathematics education. However, the findings are limited in scope, as the research was conducted within a specific context—mathematics instruction at a single school—and cannot be generalized to broader educational settings or diverse student populations. Additionally, the study did not account for varying levels of digital literacy or access to technological resources, which may affect implementation. Despite these limitations, the results provide valuable insights for educators, particularly in integrating digital tools within STEAM-based instructional designs. Teachers can use digital mind maps to deliver contextual, meaningful lessons that also enhance their professional practice. School leaders and policymakers should consider these findings when formulating strategies for digital integration, ensuring appropriate support through training and infrastructure. Future research should involve larger and more diverse sample populations, adopt longitudinal approaches to measure long-term effects, and explore the integration of emerging technologies such as artificial intelligence. Further exploration of digital mind map implementation across subjects and educational levels will also help align teaching practices with global trends in digital learning and 21st-century skills development.

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