Understanding mathematical concepts using the mind mapping learning model for high school students

Rahmat Jumri *, Haniyah Raihani Faras, Winda Ramadianti
Department of Mathematics, Universitas Muhammadiyah Bengkulu, Bengkulu 38119, Indonesia
* Corresponding Author. Email: rahmat@umb.ac.id

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Abstract: The purpose of this study is to investigate how the understanding of mathematical concepts by grade XI students at SMA N 6 Bengkulu City is influenced by the application of the mind mapping method. This study employs a quasi-experimental design with control groups. The participants consist of two sections, each with thirty-six students: XI MIPA A and XI MIPA D. The use of mind mapping techniques serves as the independent variable, while students' conceptual knowledge is the dependent variable. Measurements were conducted using tests. Data analysis compared the conceptual knowledge of the experimental and control groups using t-tests and hypothesis tests with a significance level of 5%. The findings indicate that mind mapping positively affects the students' conceptual understanding of mathematical matrices. The conceptual understanding of the experimental group improved significantly, as evidenced by the posttest results, compared to the control group that utilized conventional methods. In conclusion, the mind mapping learning model proves to be an effective tool in enhancing students' comprehension of mathematical concepts.

Keywords: Learning model, Mind mapping, Understanding concepts


INTRODUCTION

Article 3 of Law Number 20 of 2003 on the National Education System in Indonesia emphasizes the holistic development of individuals by including essential elements such as spiritual awareness, moral character, health, knowledge, creativity, independence, and social contribution. The goal is to cultivate well-rounded individuals who can positively impact society. To achieve these objectives, the education system must adapt to technological advancements by incorporating both offline and online learning processes. This dual approach aims to develop strong and competitive human resources, ensuring that Indonesian students can thrive in a rapidly evolving global landscape.

Education plays a pivotal role in shaping individuals and societies, encompassing various domains like social, cultural, and intellectual development (Upadhyay, 2022). In Indonesia, the philosophy of education, as advocated by Ki Hadjar Dewantara, emphasizes instilling cultural values and fostering holistic growth in learners (Hutagalung & Andriany, 2024). The nation's competitiveness is closely tied to the quality of its education system, highlighting the importance of enhancing human resources through education for global market advantage (Sanga & Wangdra, 2023). The development of human capital through education not only drives socio-economic growth but also enhances labor productivity, quality of life, and societal progress (Angrist et al., 2021). By focusing on comprehensive education that nurtures character and skills, Indonesia can indeed position itself favorably in the global arena.
Bloom's taxonomy encompasses two key dimensions: cognitive processes and knowledge aspects, with six categories of cognitive processes ranging from recall to creation (Wulandari et al., 2023; Kuncoro et al., 2022). The cognitive processes include recalling information, understanding concepts, applying knowledge, analyzing ideas, evaluating outcomes, and creating new solutions. On the other hand, knowledge aspects consist of factual, conceptual, procedural, and metacognitive dimensions, all crucial in fostering profound comprehension (Wulandari et al., 2023). Research has shown that these dimensions are interrelated rather than independent, highlighting the importance of considering both when designing educational assessments (Larsen et al., 2022). The taxonomy's application in educational settings emphasizes the need to incorporate higher-order thinking skills to enhance students' critical thinking abilities and promote meaningful learning experiences (Ghanizadeh et al., 2020).

Understanding, as part of the cognitive domain, is the main focus of education from the primary to secondary school levels. Students are considered to understand a concept when they can interpret information orally, in writing, or graphically (Polat et al., 2021). This understanding involves the ability of students to form a relationship between new knowledge and what they have previously acquired. Concepts in the brain are composed of cognitive frameworks and systems, and understanding is built on this foundation of conceptual knowledge (Tan, 2019).

Concepts and ideas are key elements in the formation of understanding. When students can re-articulate information using language or words they understand, they grasp the concepts (Murdiana et al., 2020). The application of mind mapping in the classroom involves concept introduction, demonstration of use, student involvement in mind map creation, integration with lessons, monitoring and feedback from teachers, and the use of technology to increase student creativity and collaboration. This method supports the learning process (Hanifah, 2023). Involving the specific way the human brain works, these techniques facilitate information organization, increase productivity, and improve memory retention (Monariska, 2017).

To achieve learning objectives, understanding concepts connected to the material taught in the classroom is essential (Rohmatin et al., 2023). The learning process in educational institutions involves collaborative teaching and learning between educators and students (Komarudin et al., 2021). To ensure that students can learn effectively and efficiently and achieve the best results, teachers are responsible for providing the necessary information. This process involves controlling the learning environment and developing a learning system that utilizes various strategies according to the needs of students (Riza & Barrulwalidin, 2023).

The mind mapping learning model has been known as an effective tool to help students understand various concepts across disciplines. However, research on the use of mind mapping in mathematics education is still limited. Mind mapping, which has a foundation in quantitative knowledge, utilizes the richness and color of real-life material. The relationship between knowledge becomes closer, and the logic of mathematical knowledge becomes tighter. Mind mapping opens up space for the development of creativity and independent thinking (Jayanti et al., 2023).

Many students consider mathematics difficult, a primary subject throughout schooling. This is due to the structure of mathematical content that is sometimes too focused on formulas and pays little attention to conceptual understanding. Learning math should not only be about memorization but also about students acquiring information through their own personal experiences. Every abstract idea that students learn in a mathematical context needs reinforcement to be applied in everyday thinking and behavior (Meyer & Lima, 2023).

Choosing effective teaching strategies is a challenge for teachers. Too often, teachers become the sole source of information without sufficient feedback or engagement from students. This is related to the use of inadequate teaching methods. As a result, the teaching and learning process becomes less interesting (Putri & Nur, 2022). Students report boredom, loss of interest, and a preference for solitary activities. While learning still occurs, conceptual
understanding does not develop optimally, and students become passive in retrieving information because they rely solely on the teacher and do not seek other sources.

Students in grade XI often have difficulty understanding content that requires foundational skills. Instead of genuinely understanding the subject, they are more likely to rely on memorization to maintain their academic performance. Students who experience this kind of difficulty encounter challenges in explaining and remembering the material that has been taught (Kholid et al., 2021). This condition is reflected in quiz results, which remain below the KKM score.

Therefore, the implementation of teaching methods that consider students’ preferences and needs is crucial (Jeheman et al., 2019). The learning process will become more engaging for students if teachers can find solutions to these problems. In this study, mind mapping is used because it helps students remember what has been taught (Loc & Loc, 2020). Additionally, because information is presented using a variety of colors, images, and symbols, this tactic can motivate students to concentrate harder and retain information. It facilitates students understanding of the concepts taught in the teacher's lessons. This study aims to determine how well the students of SMA N 6 Bengkulu City understand mathematical concepts through mind mapping. Furthermore, this research contributes to the development of innovative and effective methods for teaching mathematics.

**METHOD**

This study conducted a quasi-experiment at SMA Negeri 6 Bengkulu City in October and November 2022, utilizing an unequal control group design. A quasi-experimental design was selected to evaluate the effectiveness of the mind mapping learning model due to its ability to approximate experimental conditions in a real-world educational setting (Harwell, 2011). The population analysis involved all students of class XI MIPA A and class XI MIPA D, each comprising 36 students. Students from class XI MIPA A were assigned to the experimental group, while students from class XI MIPA D formed the control group, ensuring a balanced comparison.

The experimental group was taught using the mind mapping learning model, which included interactive mind mapping activities and visual aids, while the control group followed traditional teaching methods. Data were collected through essay tests administered before and after the intervention. Instrument validity was assessed using SPSS Version 17.0, with items considered invalid if they did not meet the predetermined statistical thresholds for reliability and content validity.

Pretests and posttests were administered under controlled conditions to both groups to assess their comprehension of mathematical concepts before and after the intervention (Cresswell, 2017). Of the 40 pretest and posttest items, ten were considered invalid and were removed based on the results. The analysis used 30 pretest questions and 30 posttest questions. The homogeneity of variances was tested using ANOVA, and the Kolmogorov-Smirnov test was used to confirm that the data distribution was normal. The mean scores of the experimental and control groups were then compared using an independent t-test to assess conceptual knowledge differences between the experimental and control groups.

Data were analyzed using SPSS Version 17.0 to verify the validity and reliability of the results and to evaluate the hypothesis. If the computed t-value is less than or equal to the critical t-value, the null hypothesis (H₀) is accepted. Conversely, if the calculated t-value is larger than the critical t-value, the null hypothesis (H₀) is rejected.
RESULTS AND DISCUSSION

Results

The experimental and control classes received the test twice: once as a pretest and once as a posttest. The results of the pretest for the experimental and control classes are shown in Table 1.

<table>
<thead>
<tr>
<th>Data</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (mean)</td>
<td>63.55</td>
<td>61.08</td>
</tr>
<tr>
<td>Median</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>Mode</td>
<td>60</td>
<td>51</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>16.18</td>
<td>18.46</td>
</tr>
<tr>
<td>Range</td>
<td>63.5</td>
<td>66</td>
</tr>
<tr>
<td>Minimum Score</td>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The experimental group’s mean score on the pretest was 63.55, while the control group’s score was 61.08. These results are summarized in Table 1. The experimental group had an average posttest score of 80.8, while the control group’s score was 71.21. These findings are shown in Table 2.

<table>
<thead>
<tr>
<th>Data</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (mean)</td>
<td>80.8</td>
<td>71.21</td>
</tr>
<tr>
<td>Median</td>
<td>82.5</td>
<td>69</td>
</tr>
<tr>
<td>Mode</td>
<td>75</td>
<td>57</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>12.23</td>
<td>15.4</td>
</tr>
<tr>
<td>Range</td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>Minimum Score</td>
<td>54</td>
<td>43</td>
</tr>
<tr>
<td>Maximum Value</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The next step involves conducting a normality test to determine if the data is normally distributed. Data is considered normally distributed if the significance value of the normality test is greater than 0.05; if it is less than 0.05, the data distribution is irregular. The experimental class’s Levene pretest result was 0.915, while the control class’s posttest result was 3.262. The experimental class’s pretest significance value was 0.343, while the control class’s posttest significance value was 0.077.

<table>
<thead>
<tr>
<th>Group</th>
<th>Data</th>
<th>Kolmogorov-Smirnov</th>
<th>Asymp.Sig.(2-tailed)</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>Pretest</td>
<td>1.0302</td>
<td>0.249</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>0.7435</td>
<td>0.659</td>
<td>Normal</td>
</tr>
<tr>
<td>Control</td>
<td>Pretest</td>
<td>1.0294</td>
<td>0.250</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>0.5133</td>
<td>0.956</td>
<td>Normal</td>
</tr>
</tbody>
</table>

As shown in Table 3, the asymptotic significance (Asymp) values for the experimental class in the Kolmogorov-Smirnov test with two tails were 0.249 for the pretest and 0.659 for the posttest. For the control group, the Kolmogorov-Smirnov pretest and posttest Asymp values were 0.250 and 0.956, respectively. Levene’s test was used to evaluate variance homogeneity, and the Kolmogorov-Smirnov test was employed to verify normality. These tests ensure that the assumptions necessary to perform an independent t-test are satisfied.

The pretest sig value was 0.343 and the posttest Lavene was 0.915. The purpose of comparing posttest results is to determine whether the mind mapping method impacts the
conceptual understanding of the experimental group. The following hypotheses were investigated:

- $H_a$: Mind mapping techniques have a significant impact on students' learning.
- $H_0$: Mind mapping techniques have no significant impact on students' conceptual knowledge.

According to the research criteria, $H_a$ is accepted and $H_0$ is rejected if the $t$-table estimated value (or sig) is less than 0.05, indicating a significant difference between the experimental group’s and the control group’s posttest findings. Conversely, $H_a$ is rejected and $H_0$ is accepted if the estimated value of the $t$-table (or sig) is more than 0.05, suggesting no discernible difference between the posttest results of the experimental group and the control group.

| Table 4. Results of Pretest and Postes Test for Experimental and Control Classes |
|------------------|-----------------|-----------------|------------------|
| Data             | Results         | Asymp sig (2-tailed) | Conclusion      |
| Pretest          | Independent t-test | 0.521            | 0.605            | No Difference   |
| Experimental- Control |                  |                   |                  |
| Posttest         |                  | 2.548             | 0.014            | There is a Difference |
| Experimental- Control |                  |                   |                  |

From Table 4, it is observed that the $t$-count (0.521 < 2.007) with the Asymp (2-tailed) significance value of 0.605, which is greater than 0.05, indicates no significant difference between the pretest results for the experimental class and the control class. Therefore, $H_a$ is rejected and $H_0$ is accepted for the pretest results. However, the findings of the hypothesis test show a substantial difference in the posttest scores between the experimental and control groups, supporting the rejection of the null hypothesis ($H_0$) and the acceptance of the alternative hypothesis ($H_a$).

Discussion

This study aims to determine how the mind mapping method affects the knowledge of grade XI students at SMA N 6 Bengkulu City. The research was conducted over six sessions from March to April 2023. Pretests and posttests were performed on the experimental and control groups to ensure their initial conceptual understanding. This is shown by comparable pretest scores, with the experimental class receiving an average score of 63.53 and the control class receiving an average score of 61.07. The $t$-test pretest analysis found a $t$-value (0.521 < 2.006) with an Asymp sig (2-tailed) of 0.605 > 0.05, indicating no significant difference in the pretest results between the experimental and control classes.

After the pretest, both classes employed different teaching methods to explore the impact on students' understanding of matrices. The control group continued with traditional lecture-based instruction, which typically involves the teacher presenting the material and students taking notes and solving problems individually. In contrast, the experimental group was introduced to mind mapping, an innovative teaching method aimed at enhancing learning through visual representation. Over several sessions, students in the experimental group created mind maps to visualize and interconnect various mathematical concepts related to matrices. This approach allowed them to see relationships between different ideas, fostering a deeper understanding and aiding memory retention. By comparing the outcomes of these two groups, the study aimed to determine whether mind mapping could be a more effective pedagogical tool than traditional lecture-based teaching in enhancing students' grasp of complex mathematical concepts.

In the second meeting, examples of mind mapping were shown to engage students, who were then divided into three groups. Students read material about matrices and created mind maps on topics such as matrix inverses, systems of linear equations (SPLDV), and matrix determinants. By the third meeting, students showed increased enthusiasm for mind mapping, producing deeper and more diverse content. This continued in the fourth meeting, with
students creating mind maps to better understand matrix-related topics. Teachers assisted students by discussing and recording their work on the board.

In the fifth meeting, students were once again divided into groups, each focusing on different mathematical concepts such as matrix inverses, systems of linear equations in two variables (SPLDV), and matrix determinants. This group-based approach, integral to the mind mapping model, significantly enhanced student engagement in the learning process (Turisia, 2022). Students actively adapted the current material on matrix inverses to suit their individual learning needs, with group formations strategically designed to assess their comprehension of matrix concepts. Both teachers and students participated in discussions about their mind mapping projects, fostering a collaborative and interactive learning environment.

The sixth meeting concluded with students and teachers summarizing the matrix concepts based on previous discussions. The study ended with a posttest in both classes to determine any variations in topic understanding before and after the intervention. The experimental class received an average posttest score of 80.06, compared to 71.21 for the control group, showing an 8.85-point difference in favor of the experimental group. This aligns with constructivist theory, which states that students actively build knowledge through social interaction and hands-on experience (Sugrah, 2019).

Posttest data revealed a significant difference in the conceptual knowledge between the experimental group, which utilized the mind mapping method, and the control group, which followed traditional teaching methods. The mind mapping approach not only enhanced students’ understanding of the material but also significantly improved their creative thinking skills and their ability to generate new ideas. This suggests that incorporating mind mapping into the curriculum can be an effective strategy for fostering both conceptual comprehension and creative ideation in students (Wulandari et al., 2019).

A statistical comparison of posttest results revealed $t_{\text{count}}$, $\text{sig}$, and $t_{\text{table}}$ values of 2.548, 0.014, and 2.004, respectively. This indicates that the mind mapping approach significantly impacted the conceptual knowledge of grade XI students at SMA N 6 Bengkulu City, as evidenced by the $t_{\text{count}}$ being greater than the $t_{\text{table}}$ and $\text{sig} < 0.05$.

This finding supports the assertion by Zulkarnain and Sari (2014) that students using the guided discovery model with mind mapping techniques improve their comprehension of mathematical concepts more than those using conventional methods. Their research demonstrated that the structured approach of guided discovery, combined with the visual and organizational benefits of mind mapping, creates an engaging learning environment that facilitates deeper understanding and retention of mathematical principles. The guided discovery model encourages students to explore and construct knowledge actively, while mind mapping helps them visualize relationships and hierarchies among concepts (Hidayati et al., 2022).

Further supporting this, Monariska (2017) found that students learning with the guided discovery model and mind mapping method show a significantly better understanding of mathematical concepts compared to those taught with traditional methods. The study revealed that students not only grasped complex mathematical ideas more thoroughly but also displayed a more positive attitude towards learning mathematics. This positive response is crucial as it suggests that students are more likely to engage with the material and persist through challenges when taught using these innovative methods (Howell, 2021).

The results of these studies suggest that incorporating mind mapping into the curriculum can enhance students' understanding of complex mathematical concepts, encouraging active learning and helping students organize and retain information more effectively. Mind mapping serves as a powerful tool in education, aiding in the clarification of complex subjects and promoting a more interactive and student-centered approach to learning (Yen & Gamble, 2021). By visually mapping out concepts, students can better see connections and relationships, making it easier to integrate new information with prior knowledge, ultimately
leading to improved academic performance and deeper comprehension (Machado & Carvalho, 2020).

CONCLUSION

This study shows that mind mapping has a positive effect on students' conceptual understanding of mathematical matrices in grade XI of SMA N 6 Bengkulu City. The conceptual understanding of the experimental group improved significantly, as demonstrated by the posttest results, utilizing a design that included both the experimental group (mind mapping) and the control group (conventional methods). The findings demonstrated that the experimental group, which used mind mapping, showed a significant improvement in their conceptual understanding compared to the control group, as evidenced by higher posttest scores. The results of the prerequisite tests also validated the statistical analysis, showing the normal distribution and homogeneity of the data between the experimental and control groups.

The importance of mind mapping as a learning tool was revealed, allowing students to organize information, form relationships between concepts, and visualize mathematical material more easily. Students who engage in mind mapping tend to develop a deeper understanding, as reflected in the increase in posttest scores. With these findings, educators are encouraged to integrate mind mapping into their teaching strategies to enhance the effectiveness of mathematics instruction and improve students' conceptual understanding. A better understanding of mathematical concepts not only impacts academic achievement but also forms a solid foundation for understanding complex concepts at the next level of high school or in other areas.

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REFERENCES


