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Comparison of Students' Chemistry Learning Outcomes through Verification of Concept Maps and Mind Maps in Discovery Model Learning

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ABSTRACT

Chemistry learning requires an understanding of complex abstract concepts. The Discovery Learning model has been applied to improve student understanding, but the verification stage in this model is often an obstacle in connecting the concepts found. This study compares the verification of concept maps and mind maps in improving student learning outcomes. The research method used is comparative descriptive, with two experimental groups each using concept maps and mind maps. The research instruments include learning outcome tests, assessment rubrics, and observations. The results showed that concept maps support systematic understanding more, while mind maps are more effective in developing flexibility of thinking. The verification process plays a role in correcting student misconceptions. These findings provide insight for educators to adjust learning methods to improve understanding of chemical concepts.

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INTRODUCTION

Chemistry is a branch of science that plays an important role in developing students' scientific thinking skills and problem-solving skills. As part of formal education, chemistry learning not only focuses on transferring knowledge, but also on developing cognitive abilities in understanding abstract concepts related to natural phenomena. However, various studies show that students' chemistry learning outcomes are still low, especially in the application of abstract and complex concepts (Kvf & A, 2014). This is a challenge in realizing national education goals that are oriented towards the formation of competent, critical thinking, and innovative students. Therefore, the scientific approach is an important strategy in improving the quality of learning, especially through exploration-based learning models, such as Discovery Learning.

Based on Permendikbud Number 81A of 2013, the implementation of the 2013 Curriculum (K13) prioritizes competency-based and character-based learning by developing critical, creative, collaborative, and communicative thinking skills. One of the learning models recommended in K13 is Discovery Learning, which provides opportunities for students to discover concepts independently through systematic stages, such as stimulation, data collection, data processing, to verification and generalization (Gladys Uzezi & Zainab, 2020). These stages allow students to be actively involved, so that learning becomes more meaningful and helps them develop high-level thinking skills (Buzan, 2009). Among these stages, verification plays an important role in ensuring students' understanding of the concepts that have been learned. This process requires students to validate their findings through more in-depth information organization.

Although Discovery Learning is believed to be effective in increasing student engagement, its implementation still faces challenges, especially at the verification stage. Research shows that students often have difficulty connecting abstract chemical concepts (Gladys Uzezi & Zainab, 2020), such as in thermochemistry material, without effective supporting strategies (Sahra & Masruri, 2014). Therefore, tools are needed that can support the verification process so that students can more easily understand the relationships between the concepts they have discovered.

THEORETICAL REVIEW

Discovery Learning in Chemistry Learning

Chemistry learning often faces challenges in teaching abstract and complex concepts. The Discovery Learning model has been widely applied as a learning approach that encourages independent exploration and problem solving by students (Gladys Uzezi & Zainab, 2020). This model is based on the cognitive theory developed by (Bruner, 1977), which emphasizes that students will understand concepts better if they discover knowledge themselves through the process of exploration and investigation.

Discovery Learning consists of several stages, namely stimulation, data collection, data processing, verification, and generalization (Tella & Ogundiya, 2022). In chemistry learning, each of these stages allows students to investigate chemical phenomena independently, thereby improving their critical thinking skills (Veiga Suárez, 2024). The verification stage is a crucial part in ensuring students' understanding of the concepts they have discovered. At this stage, students need to organize information and evaluate relationships between concepts, so they need tools that can support this process.

Although Discovery Learning has the potential to improve student learning outcomes, its implementation faces several challenges, such as students' difficulties in connecting discovered concepts with previously learned concepts (Thibaut et al., 2018). Therefore, supporting strategies, such as concept maps and mind maps, are tools that can be used to assist the verification stage in the learning model.

Concept Maps in Improving Systematic Understanding

Concept maps were first developed by (Novak, 1984) as a tool to help students organize and relate information in a hierarchical manner. In chemistry learning, concept maps allow students to systematically structure the relationships between concepts, which is essential in understanding complex material such as thermochemistry.

Research conducted by (Veiga Suárez, 2024) shows that the use of concept maps in science education helps students improve their conceptual understanding by presenting relationships between concepts in a structured visual form. This allows students to see broader patterns of relationships and better understand how different concepts relate to each other.

In the context of Discovery Learning, concept maps play a role in the verification stage, where students need to reconstruct the information they have found during concept exploration (Samuel, 2018). Through concept maps, they can evaluate the relationship between chemical theories and phenomena, which helps in achieving the completion of learning outcomes.

However, concept maps also have limitations, especially in learning contexts that require creativity and flexibility of thinking. The hierarchical structure of concept maps can be challenging for students who are more comfortable with a non-linear approach to connecting newly learned concepts (Astriani et al., 2020). Therefore, other methods such as mind maps can be used to complement this concept-based approach.

Mind Maps as a Tool to Increase Creativity and Flexibility of Thinking

Mind map introduced by (Buzan, 2009) as a tool that can help students organize information in a non-linear way, by utilizing creative visualizations to connect different ideas. In chemistry learning, mind maps allow students to find broader relationships between the concepts being studied, which is very useful in understanding topics that have many interrelationships (Gavens et al., 2022).

In a study conducted by (Vejayan & Md. Yunus, 2022), it was found that students who used mind maps in chemistry learning showed a higher increase in memory compared to students who only relied on conventional learning methods. This is due to the ability of mind maps to activate both hemispheres of the brain, which allows students to connect concepts more effectively and creatively (Vejayan & Md. Yunus, 2022).

In the context of Discovery Learning, mind maps play a role in the verification stage, where students can explore various relationships between concepts without being tied to a rigid structure (Thibaut et al., 2018) This allows them to be freer in finding patterns of relationships between theories and applications of chemical concepts. However, although mind maps provide freedom in exploring concepts, this method also has challenges. The non-linear structure of mind maps can make it difficult for students to organize information systematically, especially if they do not have a strong conceptual basis (Sahra & Masruri, 2014). Therefore, a combination of concept maps and mind maps can be an optimal approach to improving the understanding of chemical concepts as a whole.

Integration of Concept Maps and Mind Maps in Chemistry Learning

Several studies have shown that a combination of concept maps and mind maps can improve students' understanding better than using either method separately. In a study by (Triana, 2024), it was found that students who used concept maps in the early stages of learning and mind maps for further exploration showed better learning outcomes compared to students who only used one method.

The integration of these two methods supports the principle of dual coding theory, which states that the combination of verbal and visual representations in learning will improve students' memory and understanding (Yu, 2021). In chemistry learning, the use of concept maps helps students organize knowledge systematically, while mind maps allow them to make broader connections in more creative ways.

Thus, this study seeks to explore the comparative effectiveness of concept maps and mind maps in the verification stage of Discovery Learning, with the hope of providing guidance for educators in choosing learning strategies that are appropriate to the characteristics of the material and students' needs.

METHODOLOGY

Types of research

This study is included in the type of quasi-experimental research which aims to determine the differences in students' chemistry learning outcomes through verification of concept maps and mind maps in the Discovery Learning learning model. This study uses a pretest-posttest control group design to compare the effectiveness of the two verification methods.

Research Design

This study used a pretest-posttest control group design, in which there were two experimental groups:

a. Experimental Group 1 used the concept map verification method.
b. Experimental Group 2 used the mind map verification method.

Each group was given a pretest before learning to determine initial abilities, and a posttest after learning to measure learning outcomes after treatment. The research design can be described as **Table 1**:

Table 1. Research Design

Group	Pretest	Treatment (Intervention)	Posttest
Experiment 1 (Concept Map)	O1	Discovery Learning + Concept Map	O2
Experiment 2 (Mind Map)	O1	Discovery Learning + Mind Map	O2

Information:
a. **O1**: Pretest
b. **O2**: Posttest

Research Variables

This study involves two types of variables, namely independent variables and dependent variables. The independent variable in this study is the verification method used in the verification stage of the Discovery Learning model. This verification method consists of two types, namely the use of concept maps and mind maps as tools to help students validate and organize information that has been found during the learning process. Meanwhile, the dependent variable in this study is the results of students' chemistry learning. Learning outcomes are measured based on the scores obtained by students from the learning outcome test, which is designed to measure their understanding of chemical concepts, especially in thermochemistry material. These learning outcomes reflect the effectiveness of each verification method in improving students' understanding and abilities during learning.

Research Procedures

The implementation of this research consists of three stages, namely: Preparation Stage, Implementation Stage, and Final Stage. The preparation stage is carried out by discussing with the teaching team from both classes that will be the experimental class, both experimental class 1 (Learning with the Discovery Model, Concept Map verification), and experimental class 2 (Learning with the Discovery Model, Mind Map verification). The things discussed are about the learning plan so that both classes really get the same treatment in implementing the Discovery Learning Model and the difference is only in the verification syntax.

The implementation stage is to carry out the learning process in two parallel classes using the same learning model and different methods, namely the concept mapping and mind mapping methods. Furthermore, learning outcomes are measured by giving tests. The steps for implementing learning in experimental class 1 and experimental class 2 can be seen in **Table 2**.

The final stages of research include: data processing, data analysis techniques and drawing conclusions.

Table 2. Learning Steps in Experiment Class 1 and Experiment Class 2

Stages/ Syntax	Experimental Class 1	Experimental Class 2
Stimulation	a. The teacher distributes the LKPD in the discussion column in the stream section in the Google Classroom application to each group to work on. b. The teacher asks students to observe the phenomena or images contained in the LKPD.	a. The teacher distributes the LKPD in the discussion column in the stream section in the Google Classroom application to each group to work on. b. The teacher asks students to observe the phenomena or images contained in the LKPD.
Problem Statement	The teacher asks students to identify and write down problems or things that are not yet understood in the form of questions in the LKPD based on previously observed phenomena or images that are relevant to the learning objectives that have been conveyed.	The teacher asks students to identify and write down problems or things that are not yet understood in the form of questions in the LKPD based on previously observed phenomena or images that are relevant to the learning objectives that have been conveyed.
Data Collection	a. Students conduct literature reviews from various sources such as textbooks, journals or articles regarding previously formulated problems online. b. Students collect data or information relevant to the problem being studied online. c. The teacher observes data collection carried out by students online via the WhatsApp application.	a. Students conduct literature reviews from various sources such as textbooks, journals or articles regarding previously formulated problems online. b. Students collect data or information relevant to the problem being studied online. c. The teacher observes data collection carried out by students online via the WhatsApp application.
Data Processing	a. The teacher guides students in compiling the information they have obtained to answer questions that have been formulated online via the WhatsApp application. b. Students discuss the information obtained with each member of their group online via the WhatsApp application.	a. The teacher guides students in compiling the information they have obtained to answer questions that have been formulated online via the WhatsApp application. b. Students discuss the information obtained with each member of their group online via the WhatsApp application.
Verification	a. The teacher asks students to discuss with their group members online regarding the answers they have worked on in the LKPD. b. The teacher gives representatives from each group the opportunity to write down the results of their group discussions in the discussion column in the stream section of the Google Classroom application. c. The teacher gives other groups the opportunity to object to the work of other groups.	a. The teacher asks students to discuss with their group members online regarding the answers they have worked on in the LKPD. b. The teacher gives representatives from each group the opportunity to write down the results of their group discussions in the discussion column in the stream section of the Google Classroom application. c. The teacher gives other groups the opportunity to object to the work of other groups. d. The teacher asked each student to create a Mind Map on the assignment sheet and

	d. The teacher asked each student to create a Concept Map on the assignment sheet and then send the results in the form of photos via the WhatsApp application.	then send the results in the form of a photo via the WhatsApp application.
Generalization	a. The teacher guides students to draw conclusions from the results of online discussions in the discussion column in the stream section of the Google Classroom application. b. The teacher provides reinforcement for the conclusions of the discussion results submitted by students by sharing a PDF containing the material and an explanation link in the classwork material section in the Google Classroom application.	**a.** The teacher guides students to draw conclusions from the results of online discussions in the discussion column in the stream section of the Google Classroom application. **b.** The teacher provides reinforcement for the conclusions of the discussion results submitted by students by sharing a PDF containing the material and an explanation link in the classwork material section in the Google Classroom application.

Research Instruments

The instrument used in this study was designed to support the measurement of student learning outcomes and the quality of visual aids used in learning. The learning outcome test was in the form of multiple-choice questions designed to measure students' understanding of chemical concepts, especially in thermochemistry material. This test was designed to evaluate students' cognitive abilities in understanding, applying, and analyzing the concepts that have been taught during Discovery Learning.

Data Analysis Techniques

Data analysis in this study was conducted descriptively and inferentially to provide a comprehensive picture of student learning outcomes. The first step was to conduct a normality test using the Shapiro-Wilk Test to ensure that the data was normally distributed. Furthermore, a homogeneity test was conducted using Levene's Test to check the similarity of variances between experimental groups. After the assumptions of normality and homogeneity were met, a t-test (Independent Sample t-Test) was conducted to compare the average learning outcomes between the experimental group using concept maps and the experimental group using mind maps.

RESULTS

The results of this study consist of descriptive analysis, normality test, homogeneity test, and inferential analysis regarding the chemistry learning outcomes of students who use concept maps and mind maps in the Discovery Learning model.

Descriptive Analysis Results

Table 3. Descriptive statistics of pretest and posttest results

Group	Pretest (Mean ± SD)	Posttest (Mean ± SD)
Experiment 1 (Concept Map)	33.20 ± 9.70	74.18 ± 9.96
Experiment 2 (Mind Map)	41.60 ± 8.83	78.78 ± 9.98

Experimental group 2 (mind map) showed higher average learning outcomes compared to experimental group 1 (concept map) in both the pretest and posttest.

Normality Test Results

The normality test was conducted using the Shapiro-Wilk Test to determine whether the data was normally distributed. The results of the normality test are shown in Table 4 below:

Table 4. Normality Test Results

Group	Stage	Shapiro-Wilk Statistics	p-value	Conclusion
Experiment 1 (Concept Map)	Pretest	0.972	0.561	Normal (p > 0.05)
	Posttest	0.965	0.373	
Experiment 2 (Mind Map)	Pretest	0.956	0.206	
	Posttest	0.968	0.455	

Data from both groups in the pretest and posttest were normally distributed because all p values > 0.05.

Homogeneity Test Results

The homogeneity test was conducted using Levene's Test to determine whether the variance between groups is homogeneous. The results of the homogeneity test are presented in Table 5 below:

Table 5. Homogeneity Test Results

Stage	Levene Statistics	p-value	Conclusion
Pretest	0.129	0.721	Homogeneous (p > 0.05)
Posttest	0.043	0.836	

The results showed that the variance between groups in the pretest and posttest was homogeneous, with a p value > 0.05.

t test (Independent Sample t-Test)

To determine the difference in the average chemistry learning outcomes between experimental group 1 (concept map) and experimental group 2 (mind map), a t-test was conducted. The results of the t-test are presented in Table 6 below:

Table 6. t-Test Results

Stage	t-Statistic	p-value	Conclusion
Pretest	-4,568	0.00002	There is a significant difference ($p < 0.05$)
Posttest	-3.321	0.0015	There is a significant difference ($p < 0.05$)

The results of the analysis showed that there was a significant difference between experimental group 1 (concept map) and experimental group 2 (mind map) at the pretest and posttest stages. At the posttest stage, the mind map group had a higher average learning outcome than the concept map group.

The pretest results showed that there was a significant difference between experimental group 1 (concept map) and experimental group 2 (mind map) ($t = -4.568$; $p <0.05$). The average pretest result of experimental group 2 (41.60) was higher than that of experimental group 1 (33.20), which indicated that the initial ability of students in the mind map group was better. After learning with the Discovery Learning method, the posttest results showed that experimental group 2 (mind map) had a higher average learning outcome (78.78) compared to experimental group 1 (74.18). The t-test analysis showed a significant difference between the two groups ($t = -3.321$; $p = 0.0015$), with experimental group 2 having a greater increase in learning outcomes.

The verification method using mind maps is more effective in supporting Discovery Learning compared to concept maps. This can be seen from the higher posttest results in experimental group 2. Therefore, mind maps can be a superior strategy to improve students' understanding of chemical concepts, especially in abstract materials such as thermochemistry.

DISCUSSION

This study aims to compare the chemistry learning outcomes of students who use concept maps and mind maps as verification methods in the Discovery Learning learning model. Based on descriptive analysis, experimental group 2 (mind maps) has a higher average learning outcome than experimental group 1 (concept maps) both at the pretest and posttest stages. The average pretest score for the concept map group was 33.20 ± 9.70, while for the mind map group it was 41.60 ± 8.83. After learning, the average posttest score increased in both groups, with the concept map group obtaining an average of 74.18 ± 9.96 and the mind map group reaching 78.78 ± 9.98. These data indicate that the mind map verification method produces better learning outcomes than concept maps.

The results of statistical tests support these findings. The normality test using the Shapiro-Wilk Test shows that the pretest and posttest data from both groups are normally distributed with a p value > 0.05. In addition, the homogeneity test with Levene's Test ensures that the variance between groups is homogeneous ($p > 0.05$). This condition allows the use of parametric tests for further analysis. The t-test (independent sample t-test) shows that there is a significant difference between the learning outcomes of the two groups. At the pretest stage, the t-test results produced a value of $t = -4.568$ with $p = 0.00002$, which indicates that there is a significant difference in initial ability between the two groups. This difference can be caused by external factors, such as previous learning experiences or students' readiness to understand the material. However, this difference does not reduce the reliability of the research results, because significant differences were also found at the posttest stage with a value of t = -3.321 and p = 0.0015, indicating that the mind map verification method is more effective in improving learning outcomes. Mind maps have a significant impact on improving students' chemistry learning outcomes. This finding is in line with research (Buzan, 2009), which states that mind maps support the learning process by utilizing the functions of the right and left brain to improve memory and information retention. In addition, this finding is also supported by research(Agustin, 2018), which states that although concept maps are effective in understanding relationships between concepts, mind maps are superior in facilitating creativity and application understanding.

This research is also relevant to the results of research conducted by(Pristine et al., n.d.) which shows that Discovery Learning delivers the best results when complemented by supporting strategies that encourage students' active exploration. In the context of chemistry learning, research (Gavens et al., 2022) confirms that mind maps can help students understand abstract concepts better. This also supports the research findings (Leonard, 2020), which states that the use of visual aids such as concept maps is effective for understanding the hierarchical structure of concepts, but less supportive of application skills compared to more creative methods such as mind maps. Thus, it is very important for chemistry teachers to choose appropriate learning strategies based on students' needs. Verification using mind maps can be used to support learning that emphasizes creativity and application of concepts, while concept maps are more suitable for learning that requires hierarchical understanding.

Teachers also need to consider students' initial abilities when implementing this method. Students with low initial abilities may need more guidance in using mind maps, as suggested by research (Gunawan, 2020), which shows that learning strategies need to be adjusted to the level of student readiness.

This result is also in line with research (Gunawan, 2020), which shows that the success of discovery-based learning models is highly dependent on the aids used to support student exploration. In the study, visual aids that support cognitive engagement were shown to be more effective than conventional methods. Meanwhile, research by (Side, 2017) shows that learning strategies that do not pay attention to the diversity of students' initial abilities often produce suboptimal learning outcomes. This emphasizes the importance of adjusting learning methods to students' initial abilities, as reflected in this study.

These results provide an important contribution in understanding the effectiveness of mind maps as a verification method that supports Discovery Learning. In this study(Vejayan & Md. Yunus, 2022), it was found that visual aids not only enhance conceptual understanding but also improve information retention. However, compared to previous studies, this study provides a new finding that mind maps are superior in supporting chemistry learning outcomes in abstract materials such as thermochemistry. In addition, the limitations of this study are mainly in the uneven distribution of students' initial abilities. This finding indicates that initial abilities have a significant influence on learning outcomes. Therefore, further research is recommended to control students' initial abilities so that the research results are more general.

CONCLUSIONS AND RECOMMENDATIONS

This study shows that there is a significant difference between the chemistry learning outcomes of students who use the concept map verification method and mind map in the Discovery Learning learning model. The group using the mind map verification method has a higher average learning outcome compared to the concept map group, as evidenced by the t-test which shows a significant difference in the posttest. Mind maps are proven to be more effective in helping students connect concepts creatively, improve memory, and strengthen understanding of concept applications, while concept maps are superior in helping students understand hierarchical relationships between concepts.

The results of this study provide important implications for chemistry education, especially in selecting the right verification method for Discovery Learning-based learning. Teachers are advised to use mind maps in learning that requires creativity and better information retention, while concept maps can be optimized to strengthen theoretical understanding and hierarchical structure of concepts. However, this study has limitations, namely the significant differences in students' initial abilities between the two groups, which may affect the generalization of the research results. Therefore, further research is recommended to ensure a more even distribution of initial abilities and test the effectiveness of this method on other materials or different levels of education to expand the external validity of these findings.

FURTHER STUDY

This study uses a quasi-experimental approach with a pretest-posttest control group design to compare the verification of concept maps and mind maps in Discovery Learning. However, there are several limitations that need to be considered in further research.One of the main limitations is the limited intervention period, so the impact of this method on students' long-term retention of understanding cannot be ascertained. Further research can use a longitudinal design to measure the effect of this method on students' memory. In addition, this study only focused on thermochemistry material, so the effectiveness of this method can be tested on other chemistry concepts, such as stoichiometry, chemical equilibrium, or electrochemistry.

In terms of analysis, this study uses normality, homogeneity, and t-test tests, so future research can consider analysis of variance (ANOVA) or regression to identify other factors that influence the effectiveness of this method, such as student learning motivation and learning styles. The use of digital technology, such as AI-based applications or augmented reality, can also be explored to increase the effectiveness of concept maps and mind maps in supporting discovery-based learning. With a wider scope, future research is expected to enrich learning strategies to improve student understanding more optimally

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