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Jurnal Inovasi Pendidikan IPA, 11 (2), 2025, 454-468

Effectiveness of Discovery Learning Assisted by Chemical Monopoly on Critical Thinking and Learning Outcomes

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Received:23 April 2025; Revised: 26 May 2025; Accepted: 14 July 2025

Abstract: The purpose of this research is to determine the effect of the discovery learning model using chemistry monopoly media on the critical thinking skills and learning outcomes of 11th-grade students. This research employs a quantitative descriptive approach with a quasi-experimental design and a pretest-posttest nonequivalent control group design, utilizing instruments in the form of tests and an observation guide. The sampling technique used is cluster random sampling. Both the experimental class and the control class have 35 students. This study collected data through tests (pretest and posttest). Data analysis was conducted using normality and homogeneity tests, followed by the Mann-Whitney U test (since the data are not normally distributed), and the N-Gain test for assessing learning effectiveness. The research results indicate that the experimental class achieved a 58.79% increase in learning outcomes, whereas the control class experienced a 36.51% increase. In terms of critical thinking ability, the experimental class showed an improvement of 56.00%, while the control class improved by 37.18%. The Mann-Whitney U hypothesis test revealed the significance of cognitive learning outcomes to be 0.041 and the significance of critical thinking ability to be 0.019. Thus, the implementation of discovery learning affects students' critical thinking skills and learning outcomes in the context of acid-base chemistry.

Keywords: acids and bases, chemistry monopoly, critical thinking, discovery learning, learning outcomes

How to Cite: Martanisa et al. (2025). Effectiveness of Discovery Learning Assisted by Chemical Monopoly on Critical Thinking and Learning Outcomes. *Jurnal Inovasi Pendidikan IPA*, *10*(2), 454-468. doi:https://doi.org/10.21831/jipi.v11i2.84674

INTRODUCTION

The 21st-century learning is present as a means of preparing the 21st-century generation. The 21st-century learning framework developed by the Partnership for 21st-Century Learning requires students to have 4C skills, namely creativity, critical thinking, communication, and collaboration (Nuraeni et al., 2019). In the 21st century, critical thinking skills are considered basic competencies that need to be mastered on par with reading and writing skills (Fisher, 2011). One of the branches of science studied at the high school level is chemistry. One of the hallmarks of chemistry is the interconnectedness between its concepts, which evolve from simple ideas to more complex ones (Kean & Middlecamp, 1985). In some of the materials studied in chemistry, the topic of acid-base is one of the ten most difficult chemistry concepts for students to understand (Childs & Sheehan, (2007).

In chemistry learning, students must have the ability to think critically, because they must be able to detect and solve problems, draw conclusions, analyze, and evaluate (Pratama et al., 2017). Critical thinking skills are an essential tool, as the key to future success (Setianingsih & Roshayanti, 2022). Thus, students must master the ability to think critically so that later they can follow scientific fields according to their interests (Malikah & Wafroturrohmah, 2022). Unfortunately, the learning activities carried out have not been fully utilized to empower students' critical thinking skills.

The results of PISA 2022 support this. The results of PISA 2022 show that literacy, numeracy, and science scores are still below the average of the Organisation for Economic Co-operation and

https://doi.org/10.21831/jipi.v11i2.84674

Development (OECD), which indicates that the critical thinking skills of students in Indonesia are relatively low (OCDE, 2023). Considering that PISA questions require problem-solving skills and logical reasoning, the PISA results can be used as a benchmark to assess students' low critical thinking skills (Fauzi & Abidin, 2019).

Facione (2011) proposes six indicators of critical thinking: analysis, interpretation, explanation, evaluation, inference, and self-regulation. Meanwhile, according to Ennis (2011), critical thinking skills have five indicators, namely: basic clarification, including focusing questions, analyzing arguments, asking and answering questions about an explanation; the bases for a decision, including considering the credibility of sources, observing and considering the results of observations; inference, including making deductions and considering the results of deductions, making inductions and considering the results of inductions, and making and considering the value of decisions; advanced clarification, including identifying terms and considering definitions, and identifying assumptions; strategies and tactics, including determining actions and interacting with others. This study employs critical thinking indicators, as outlined by Ennis.

The quality of learning outcomes can be reflected in an individual's ability to think critically. This indicates that students' critical thinking skills have a direct impact on improving learning outcomes (Hidayati & Kurniawati, 2021). According to Sudjana (2010), learning outcomes are skills that students acquire after completing the learning process. Student learning outcomes can be seen from various aspects of their behavior, including mastery of knowledge, thinking skills, and motor skills (Sukmadinata, 2007).

A public high school in Central Java implementing Kurikulum Merdeka reported that learning methods mainly involved group discussions and peer question practice. However, these discussions focused more on verifying answers than developing reasoning skills, making them less effective for fostering critical thinking. Student score documentation also showed that many grade XI students did not reach the minimum passing grade of 75, indicating low cognitive achievement.To overcome this problem, it is best to use a learning model that encourages students to acquire critical thinking skills.

To overcome this problem, it is best to utilize a learning model that fosters students' acquisition of critical thinking skills. Learning experiences that encourage students to explore, research, identify, and solve problems can help improve their critical thinking skills. Discovery learning, also known as discovery-based learning, is one alternative approach to developing critical thinking skills while enhancing student learning achievement.

Wibisono (2023) states that discovery learning is a learning model designed to develop students' active learning skills, allowing them to discover and explore on their own; thus, the knowledge gained will remain more firmly attached and last longer in memory, rather than being easily forgotten by students. This model helps students maximize their potential in searching for and finding something, be it objects, people, or events, in a structured, critical, logical, and analytical way, so that students express their findings with confidence (Laeni et al., 2022).

Fun and interactive learning will last a long time in memory and make it more meaningful while increasing motivation and learning outcomes (Wahyuning, 2022). Games have great potential as a learning medium that is very motivating for students. Students can learn while playing, which can be an alternative to learning, to foster students' motivation to learn, so that it can be easier to understand the material (Mahesti & Koeswanti, 2021). One of the games that can be modified as a learning medium is Monopoly. The monopoly that will be used as a learning medium is a modified Chemical Monopoly game. Monopoly learning media can make students more engaged and increase their interest, so that they become more motivated to learn (Miranda et al., 2012).

The application of discovery learning with the game method can be concluded that this model can improve student learning outcomes (Rahmi, 2020). The discovery learning model also has a significant effect on students' critical thinking skills (Dahlan et al., 2023). Research by (Putri et al., 2024) also concluded that the discovery learning model, combined with Wordwall media, had a positive effect on critical thinking skills.

This study aims to investigate the impact of the discovery learning model, assisted by chemical monopoly media, on students' critical thinking skills and learning outcomes. The latest research is on chemical monopoly as a learning medium in the discovery learning model. This chemical monopoly has never been used before in the context of learning with the discovery learning model, making it an innovation in chemistry teaching methods.

METHOD

The research was conducted at a public senior high school in Central Java. The study was carried out in the even semester of the 2023/2024 school year. The method employed is a quantitative descriptive approach, specifically a quasi-experimental research design. It employs the pretest-posttest nonequivalent control group design, a research design in which a pretest is administered before treatment and a posttest is administered after treatment to the subject being studied.

Table 1. Pretest Posttest Nonequivalent Control Group Design

Class	Pretest	Treat	Posttest
Control	O_1	X_1	O_3
Eksperimen	O_2	X_2	O_4

Description:

O_1 : Pretest (Control Class)
O_2 : Pretest (Experimental Class)
X_1 : Treatment of learning with conventional learning, with a package book and PowerPoint slides
X_2 : Learning treatment with the discovery learning *model* assisted by chemical monopoly
O_3 : Posttest (Control class)
O_4 : Posttest (Experimental Classes)

The population in this study were grade XI students majoring in agriculture-health at a public high school in Central Java in the 2023/2024 academic year, consisting of four classes. The sampling technique used in this study was cluster random sampling, where the class served as the unit of clustering. Of the four available classes of XI agriculture-health majors, two classes were selected as samples through a lottery. This study employed two classes: a control class and an experimental class. As a result, two classes were chosen to be obtained from class XI F7, which was used as an experimental class with the learning of the discovery learning model assisted by chemical monopoly, and class XI F6, which was used as a control class with conventional learning with the help of package media and PowerPoint presentations. The chemical material studied is an acid-base. The data collection process lasted two weeks (in February 2024), but this research started from January to June 2024.

The following are the learning steps implemented in the experimental class using the discovery learning model. This learning design is prepared with reference to the research by Chusni et al. (2020) which illustrates the relationship between the discovery learning model and critical thinking skills, and is subsequently modified to meet the needs of this study. The relationship between the discovery learning model and critical thinking skills, as observed in the study, is presented in the following table.

Table 2. Learning treatment with the discovery learning model assisted by chemical monopoly

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Discovery Learning *Phase*	Critical Thinking Aspects	Critical Thinking Indicators	Student Activities
Stimulation	Elementary clarification	Asking and answering clarification questions	Students answer questions from teachers regarding the initial problem.
Problem Identification	Elementary clarification	Formulating a question	• Students identify issues relevant to the subject matter, • Formulating a hypothesis
Data Collection	Basic skills	Considering whether the source is trustworthy/not	Students play chemistry monopoly while learning from their own learning resources or available learning media
	Elementary clarification	Analyzing arguments	Students discuss in groups to answer question cards on chemical monopolies.
	Setting strategies and tactics	Defining an action	In groups, students work together to set strategies to answer questions on question cards, and will win a chemical monopoly.
Data Processing	Advanced clarification	• Identifying assumptions • Identifying terms and considering definitions	After constructing the knowledge gained through the chemical monopoly game, students work on the student worksheet.
	Setting strategies and tactics	Interacting with others	In groups, students discuss how to work on the student worksheet.
Verification	Inference	• Reducing and considering the results of deduction • Inducing and considering the results of induction	Students state the evidence and interpretation of the data from their discoveries.
Generalization	Inference	• Reducing and considering the results of deduction, • Inducing and considering the results of induction • Creating and defining consideration values	Students draw conclusions from their findings, which are used as general principles for the same problem

The teaching approach applied in the control class is conventional, commonly used by teachers in schools. Although it does not have a standard syntax like the innovative teaching model, researchers tried to map conventional teaching activities based on the results of observations and interviews with teachers into a simple syntax. The syntax was then analyzed for its relationship to aspects of critical thinking skills based on indicators from Ennis. However, the second class was still given a critical thinking skills test that covered all aspects. This was done to provide a comprehensive picture of the extent to which each class had developed its critical thinking skills.

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Table 3. Treatment of learning with conventional learning, with a package book and PowerPoint slides

Learning Phase	Critical Thinking Aspects	Critical Thinking Indicators	Student Activities
Material Explanation	-	-	Paying attention to the teacher in explaining the material
Doing Practice Questions	Strategies and tactics	Interacting with others	Discussing with their classmates to answer questions
	Basic clarification	Asking and answering an explanation question	
	Strategies and tactics	Defining an action	Determining the appropriate action to solve the problem
Discussing Practice Questions	Strategies and tactics	Interacting with others	• In class, students and teachers discuss to confirm answers • Students and teachers jointly confirm the answers to the questions
	Basic clarification	Analyzing arguments	
Drawing Conclusion	Inference	• Reducing and considering the results of deduction • Inducing and considering the results of induction • Creating and defining consideration values	Drawing conclusions about what material has been studied

Data collection was conducted through both tests and non-tests. The test included a pretest and a posttest to measure learning outcomes and critical thinking skills. This test consisted of a pretest and a posttest, each containing multiple-choice questions to measure student learning outcomes. Descriptive questions were also used to assess critical thinking skills. Multiple-choice questions consisted of 15 questions, and essay questions consisted of five questions. The non-test consisted of observations before and during the research to assess the initial condition of students and the implementation of discovery learning, as well as documentation in the form of teaching modules, learning media, and Chemistry End-of-Semester Summative Assessment (PSAS) scores for the 2023/2024 school year.

In this study, two types of instruments were used: teaching instruments and data collection instruments. Teaching instruments include teaching modules and monopoly media. Before being used, the teaching modules and chemistry monopolies were validated by two experts each.

The results of the validity test of the cognitive learning outcome instrument showed a value of > 0.70 so that it was declared valid. Meanwhile, the reliability test yielded a value of 0.80, which indicated that the instrument was reliable. Based on the results of the item analysis using the ITEMAN application, out of 15 questions tested, eight questions are in the easy category of difficulty level, and seven questions are in the medium category. Meanwhile, based on the discriminatory power test, four questions fall into the sufficient category, nine questions into the good category, and two questions into the excellent category.

The critical thinking ability assessment instrument was analyzed using the ANOVA application. The validity test results showed a value of 0.80 and were deemed valid, while the reliability was 0.88, indicating that the test was reliable. Based on the analysis of the questions, five questions were identified as being at a moderate level of difficulty. The discriminatory power test revealed that four questions were categorized as good, and one question was rated as very good.

Data analysis utilizes prerequisite tests, including the normality test and the homogeneity test. If the data were homogeneous, the hypothesis test was continued using MANOVA; if the data were not

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

normal, then it was continued with the Mann-Whitney U test. Additionally, this study employed the N-Gain test to assess the effectiveness of learning by comparing normalized *pretest* and *posttest* scores.

To calculate the n-gain score, the researchers used the following formula:

$$N\text{-}Gain = \frac{(Score\ after\ treatment)-(Score\ before\ treatment)}{Ideal\ score\ -(Score\ before\ treatment)}$$

The N-Gain interpretation categories are (Sukarelawan et al., 2024):

Table 4. N-Gain Score Category

N-Gain Score	Category
$g > 0.7$	High
$0.30 \leq g \leq 0.70$	Medium
$g \leq 0.30$	Low

The categories of interpretation of *N-Gain* effectiveness are presented in Table 5.

Table 5. Criteria for Determining the Level of N-Gain Effectiveness

Percentage N-Gain	Category
>76%	Effective
56% −75%	Quite Effective
40% − 55%	Less Effective
< 40%	Not Effective

RESULT AND DISCUSSION

The discovery learning model is an innovative approach designed to enhance the quality of classroom learning and achieve learning objectives. The discovery learning syntax serves as a guide that outlines the steps for implementing this method. This syntax covers the entire series of learning activities, providing general instructions on the types of activities carried out by the teacher, their sequence, and the tasks that students must carry out (Salamun et al., 2023).

Discovery learning has the potential to empower students' critical thinking skills. This process begins with the creation of a hypothesis that aims to provide rational arguments, starting with an orientation to real phenomena, followed by interpretation, analysis, evaluation, and concluding the experimental results. These stages, including hypothesis testing, aim to draw the correct conclusion from the experiment's results.

The learning process using the discovery learning model, assisted by a chemical monopoly, begins with the stage of providing a stimulus. This stage starts by presenting something that is confusing, thereby raising questions. Then, in the next stage, namely problem identification, students are allowed to respond by identifying problems relevant to the initial stimulus, while other students provide temporary answers. This answer is then formulated as a hypothesis.

The following learning stage is data collection, where students will collect information through playing Monopoly. In the game of chemical monopoly, there are question cards and material cards. To answer this question card, students will collect information from various sources, including material cards contained in the monopoly system. The next stage is data processing; the information obtained during data collection will be used to answer the questions in the student worksheet.

The fifth stage is verification, in which students present the answers from the discussion and are then responded to by other students. The final stage is drawing conclusions, where students determine whether the findings they obtain have supported or refuted the hypothesis.

1. Influence on Critical Thinking Ability and Learning Outcomes
   a. Normality Test

      A normality test was conducted to determine whether the sample data were normally distributed. The normality test in this study uses the Shapiro-Wilk test method with a significance of 0.050.

Table 6. Normality Test Results

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Class	Variable	Sig	Conclusion
Experimental	Critical Thinking Skills	0.307	Normal data
	Learning Outcomes	0.006	Abnormal data
Control	Critical Thinking Skills	0.163	Normal data
	Learning Outcomes	0.001	Abnormal data

Based on the results of the normality test, the difference in posttest-pretest scores is significant for both the experimental and control classes in terms of critical thinking ability, with a significance value of $p < 0.050$. Therefore, it can be concluded that the data from the two classes are normally distributed. Meanwhile, the difference in critical thinking ability between the experimental and control classes is significant at $p < 0.050$, indicating that the data is distributed abnormally. Thus, hypothesis testing will be continued with non-parametric tests.

b. Homogeneity Test

The homogeneity test was conducted to determine whether the data studied were homogeneous using a Levene statistical test with a significance level of 0.05.

Table 7. Homogeneity Test Results

Variable	Signifikansi	Conclusion
Critical Thinking Skills	0.352	Homogeneous
Learning Outcomes	0.058	Homogeneous

The results of the homogeneity test showed a significance value of more than 0.05, namely 0.352 for the difference in posttest-pretest critical thinking ability and 0.058 for learning outcomes. Therefore, it can be concluded that the data is homogeneous in variance.

c. Pretest and Posttest Results

Table 8 below summarizes the pretest and posttest scores of critical thinking skills and learning outcomes.

Table 8. Summary of Pretest and Posttest Scores for Critical Thinking Skills and Learning Outcomes

Data	Minimum Values	Maximum Value	Average
Critical Thinking Skills			
Experimental Class Pretest	18	56	39.09
Control Class Pretest	14	54	31.14
Experimental Class Posttest	52	100	73.20
Control Classes Posttest	28	90	56.74
Learning Outcomes			
Experimental Class Pretest	40	87	65.33
Control Class Pretest	33	73	54.10
Experimental Class Posttest	67	100	85.71
Control Classes Posttest	47	93	70.86

Before receiving treatment, each class was pretested to determine their initial ability. The average pretest score shown in Table 8 is both critical thinking ability and relatively low learning outcomes. After receiving treatment, a post-test was conducted. The results showed an increase in posttest scores in the experimental class. Meanwhile, the control class also improved, but the average score was lower than that of the experimental class.

2. Analysis and Interpretation

a. Critical Thinking Ability Achievement Data

The average percentage of achievement in critical thinking skills, according to the pretest score, was 39.09% for the experimental class, while the control class achieved 31.14%. Meanwhile, the percentage of achievement of critical thinking skills, based on the posttest results for the experimental class, was 73.20%, while for the control class, it was 56.74%. This indicates a significant difference in critical thinking skills between the discovery learning model, assisted by Monopoly Chemistry, and conventional learning.

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Table 9. Percentage of Achievement and N-Gain Score of Critical Thinking Ability Based on Indicators

Aspects	Critical Thinking Skills Indicators	Indicator Achievements Critical Thinking Ability (%)		N-Gain Score	
		Experimental Classes	Control Classes	Experimental Classes	Control Classes
Elementary clarification	Asking and answering questions about an explanation	89.14	73.14	0.56	0.15
	Focus questions	71.71	61.14	0.58	0.44
	Analyze arguments	82.29	57.43	0.79	0.51
Basic support	Consider whether the source is trustworthy/not.	86.86	71.71	0.57	0.50
Advanced clarification	Defining terms and considering definitions	89.14	73.17	0.56	0.15
	Identify assumptions	82.29	57.43	0.79	0.51
Interference	Inducing and considering the induction outcome	86.86	71.71	0.57	0.50
	Reducing and considering the results of deduction	36.00	20.29	0.35	0.19
	Create and define consideration values	36.00	20.29	0.35	0.19
Strategies and tactics	Define an action	71.71	61.14	0.58	0.44

Based on Table 9, it is evident that the indicators of critical thinking ability include asking and answering questions about explanations, defining terms, and considering their definitions. In the experimental class, the highest achievement was achieved, with a score of 89.14% and an N-Gain score of 0.56. The control class had a 73.14% success rate with an N-Gain score of 0.15. The use of the discovery learning model assisted by chemical monopoly will help students to analyse problems more critically, find solutions to existing challenges, and find new ideas (Galbinur et al., 2023). Questions containing indicators ask and answer questions about explanations, as well as define terms and consider definitions contained in Question 1, namely,

"Arrhenius was a Swedish chemist and one of the inventors of Physics and Chemistry. One of the widely used theories about acid-base chemistry is the Arrhenius acid-base theory. Explain Arrhenius' acid-base theory. Below are some examples of solutions. Write down the ionization reaction of these solutions! H_2SO_4, CH_3COOH, $Ba(OH)_2$, KOH"

Question 1 is to write down the definition of acid-base according to Arrhenius' theory, and to be able to write down ionization reactions. Asking students to define a theory requires them to understand the key concepts and terms that are associated with it. This entails a critical assessment of the information they have learned or gathered.

The ability to ask and answer questions from an explanation can be improved through the syntax of stimulus or stimulus, in this syntax, students are presented with something that confuses them, so that queries and activities arise to investigate themselves (Anwar et al., 2023). Defining a theory requires understanding the key concepts and terms associated with it. This requires a critical assessment of the information they have learned or gathered.

Furthermore, for indicators of analyzing arguments and identifying assumptions, the experimental class achieved a percentage of 82.29% with an N-Gain score of 0.79, which falls in the high category. Meanwhile, the control class obtained a rate of 57.43% with an N-Gain score of 0.51. These results indicate that the experimental class has superior critical thinking skills.

Indicator analysing arguments and identifying assumptions found in Question 3:

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

"Pay attention to the following solution data

Solution	*Concentration (M)*
HNO_3	*1×10^{-3}*
CH_3COOH ($Ka=10^{-5}$)	*1×10^{-1}*

The questions related to the two solutions are
1. The concentration $[H^+]$ of both solutions is the same
2. Both are strong acids
3. CH_3COOH have $\alpha= 0.01$
4. Both solutions are perfectly ionized in water
Factual statements indicated by numbers? And give the reason"

In Question 3, data and statements are presented, and students are asked to determine the correct statement and the reason. Students are to determine the correct statement and the reason written, also based on the data, and outline how the data supports or does not support a particular statement. Students from the experimental class were able to identify true and false statements, complete with the correct reasons. Meanwhile, the answers from the control class were still inaccurate in determining the correct statement.

A significant increase in the experimental class based on the results of the posttest shows the effect of the discovery learning model assisted by chemical monopoly on the ability to analyze arguments. This learning model can help students in analyzing problems more critically. During the implementation of the chemical monopoly game, students were enthusiastic about arguing based on what they had learned and contributed answers they were familiar with. In the application of discovery learning assisted by chemical monopoly, students will identify assumptions from the discussion process when playing monopoly and discuss them when working on the student worksheet.

The next critical thinking indicator is to consider whether the source is reliable or not and to evaluate the results of the experimental class, which achieved an 86.86% success rate with an N-Gain score of 0.57, placing it in the medium category. Meanwhile, the control class obtained an indicator achievement of 71.71% with an N-Gain score of 0.5.

In Question 2, there is an indicator of considering whether the source is reliable or not, inducing, and evaluating the results of induction. In this question, students can determine the appropriate procedure to obtain the degree of ionization (α) and can prove the correctness of the statements written in the question with the help of the data obtained.

"A practitioner experimented by taking 6.8 grams of NH_3 gas (Mr = 17 g/mol) and then dissolved it in water so that the volume of the solution became 1 liter with Kb NH_4OH = 10^{-5}. Therefore, the ionization degree (α) of NH_4OH is 0.005. Prove whether NH_3 is ionized in water by 0.5%"

In the discovery learning mode, students are directly involved in the learning process, namely during the data collection stage, through a chemical monopoly game. A learning environment that involves students in actively investigating information on their own and applying their knowledge allows their critical thinking skills to improve (Snyder & Snyder, 2008).

When students access information from various sources, they must be able to evaluate the truth and validity of that information, considering that not all information found is trustworthy. Additionally, when answering questions from question cards, they must make the correct decision. This requires critical thinking skills to ensure the answers they choose are correct and based on trusted sources or valid and accurate methods of answering, making them more thorough and vital in evaluating the information they obtain.

The discovery learning model assisted by chemical monopoly is quite effective in improving the determination of actions. This is because the use of monopoly media helps test students' individual intelligence, strategies, and skills, and involves students actively in learning (Sary & Dina, 2023). The percentage of achievement of indicators determining actions and focusing questions in the experimental class was 71.71%, with an N-Gain score of 0.58. In comparison, the control class achieved 61.14% with an N-Gain score of 0.44.

Indicators of determining actions and focusing questions are found in Question 4:

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

"Into 100 ml of 0.1 M HCl solution, 900 ml of water is added, then the pH of the solution will change. Determine the change in pH of the solution and analyze the change in pH of the solution."

The students' answers from the complete experimental class, which started from the initial pH and the final pH, were given an analysis, even though it was only one sentence. However, it has already been shown that the pH of HCl after dilution increased, which eventually caused its acidic properties to weaken. Meanwhile, the answer from the control class was only the pH in the end. That means students from the experimental class are more thorough in answering questions and focused on understanding them. The next indicator of critical thinking ability is to deduct and consider the value of deduction, as well as make and assess the value of decisions. In the experimental class, an achievement of 36.00% was obtained with an N-Gain score of 0.35. Meanwhile, the control class obtained 20.29% with an N-Gain score of 0.19. The results showed a significant difference.

The achievement of this indicator is affected by the generalization stage in the discovery learning model, where students are guided to make decisions by connecting various concepts of their understanding to existing information. In the generalization stage, students are actively involved in the decision-making process by associating ideas with each other based on their understanding of the information and the results of the verification that have been carried out (Anwar et al., 2023).

Question 5 contains two indicators of critical thinking skills, namely concluding and considering the value of deductions, and making and considering the value of decisions. In the question, a table of test results for solutions with several acid-base indicators is presented. Students can determine the pH range and classify solutions as acidic, basic, or neutral.

Students in the experimental class wrote down the complete pH range and concluded the nature of the solution. Students used some of the information contained in the question, specifically the color change in the indicator solution, to determine the pH range and then classified it as acidic, neutral, or basic. Meanwhile, based on the answers from the control class, students only wrote down the pH range but did not classify it into acid, base, or neutral.

The last aspect of critical thinking is strategy and tactics. This aspect comprises two indicators: interacting with others and determining actions. Interacting with others can be improved in the stages of data collection, data processing, and generalization. At the stage of data collection, students will discuss the questions on the question cards with their friends to ensure they answer them correctly. Meanwhile, at the stage of data processing, students will discuss problems with their friends to solve the issues in the student worksheet.

While the indicator suggests that the action can be improved through the data processing stage, specifically when students play Monopoly, they will evaluate a strategy to win the game. Based on the results of the observations, the strategy and tactics aspects of the experimental class achieved the highest presentation among other critical thinking aspects. The indicator *interacting with others* is at a rate of 93.71%, while the indicator determining the action is at a rate of 93.90%.

The use of games, such as the chemistry monopoly game used in this study, plays a crucial role in supporting the development of students' critical thinking skills. Games create an interactive and enjoyable learning environment, encouraging active participation, which are key conditions for the emergence of essential thinking processes.

Through game elements such as challenges, competition, and decision-making, students are encouraged to analyze problems, develop strategies, evaluate options, and draw conclusions directly. These processes align with critical thinking indicators such as making inferences, evaluating, and providing logical reasoning. Furthermore, group play activities encourage discussion, argumentation, and reflection skills that are integral to higher-order thinking.

Overall, the discovery learning model, assisted by a chemical monopoly, improves critical thinking skills in experimental classes. This is supported by the acquisition of N-Gain scores for critical thinking skills, as shown in Table 10 below.

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Table 10. Analysis of the N-Gain Test of Critical Thinking Skills Based on Class

Class	Average		$<g>$	Criteria	Percentage (%)	Interpretation
	Pretest	*Posttest*				
Experiment	39.09	73.20	0.56	Medium	56.00	Quite Effective
Control	31.14	56.74	0.37	Medium	37.18	Not Effective

Table 10 shows that the experimental class has an N-Gain of 0.56, categorized as "medium," and an effectiveness of 56.00%, indicating a reasonably practical interpretation. Meanwhile, the control class had an N-Gain score of 0.37, categorized as "medium," and an effectiveness of 37.18%, indicating an ineffective interpretation. These results demonstrate that the discovery learning model, assisted by chemical monopoly, is highly effective in enhancing critical thinking skills, as noted in the N-Gain test.

b. Learning Outcome Data

This study uses six learning objectives that students must achieve, namely explaining the acid-base properties of compounds according to several acid-base theories, calculating $[H^+]$ from acid-base compounds and $[OH^-]$ from alkaline compounds, describing the relationship between $[H^+]$ and $[OH^-]$ with ionization degrees (α) and acid (Ka) and base (Kb) settings, explaining the relationship between acid and base settings with acid and base strength, calculates the pH of acidic and alkaline compounds, determines the pH range with the acid-base indicator.

Table 11. Percentage of Learning Indicator Achievement and N-Gain Data

Learning Objectives	Learning Outcome Indicator Achievement (%)		N-Gain Score	
	Experimental Class	Control Class	Experimental Class	Control Class
1. Explaining the definition of acid-base compounds according to several acid-base theories.	89.14	73.14	0.64	0.36
2. Calculating $[H^+]$ from acidic compounds and $[OH^-]$ from basic compounds	97.14	85.71	0.75	0.62
3. Explaining the relationship between $[H^+]$ and $[OH^-]$ with the degree of ionization (α) and the acid constant (Ka) or base constant (Kb)	100	82.86	1	0.37
4. Explaining the relationship between the acid constant (Ka) or base constant (Kb) and the strength of the acid base	75.71	64.29	0.60	0.38
5. Calculating the pH of acidic and basic compounds	81.90	73.33	0.55	0.47
6. Determining pH using acid base indicators	72.86	48.57	0.44	0.16

The average achievement of learning outcomes based on pre-test for the experimental class was 66.62% while 54.16% for the control class. The average achievement of learning outcomes based on the post-test of the experimental class was 86.13% and the control class was 71.32%. These results show a significant difference.

Table 8 shows that the learning objective that has the highest achievement in the experimental class is to explain the relationship between $[H^+]$ and $[OH^-]$ with the degree of ionization and acid-base setting, which is to achieve 100%, meaning that all students in the experimental class have succeeded in attaining this learning goal. This is supported by the

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

acquisition of N-Gain in this learning objective, which is categorized as 1 with high effectiveness and 100% accuracy in effective interpretation.

Meanwhile, for the control class, the purpose is to calculate [H+] from acid compounds and [OH] from alkaline compounds, with a percentage of 85.71% and an N-Gain score of 0.62, placing it in the medium category, and an effectiveness of 61.54% with a relatively effective interpretation. Overall, the discovery learning model, assisted by a chemical monopoly, improves students' cognitive learning outcomes. This increase is supported by N-Gain results, which use the average of the values, as shown in the following table.

Table 12. N-Gain Test Analysis Data for Learning Outcomes Based on Classes

Class	Average *Pretest*	*Posttest*	<*g*>	Criteria	Percentage (%)	Interpretation
Experiment	65.33	85.71	0.59	Medium	58.79	Quite Effective
Control	54.10	70.86	0.37	Medium	36.51	Not Effective

Based on Table 12, the N-Gain score for the experimental class is 0.59, which corresponds to the criterion of "medium", and the effectiveness is 58.79%, indicating a reasonably practical interpretation. For the control class, N-Gain was obtained as 0.37, which corresponds to a "medium" criterion, and the effectiveness was 36.51%, indicating an ineffective interpretation. Based on data from both classes, it is evident that cognitive learning outcomes in the experimental class have improved more significantly than those in the control class. This finding is consistent with the previous study, which stated that in Discovery Learning with monopoly media has an effect on the percentage of student activity and increases students' cognitive learning performance (Sary & Dina, 2023). Students no longer passively receive explanations from teachers; they are independently able to identify the core material, so that every learning activity carried out focuses on seeking and developing knowledge through the investigative process (Chusni, 2022).

With the use of monopoly media that provides many question cards, students can learn more to complete problem exercises. Thus, students will learn actively, solve problems with creative solutions, and improve their ability to analyze and create new information (Galbinur et al., 2023).

In the experimental class, students are given the freedom to solve problems and allowed to gain new experiences in expressing ideas as well as exchanging opinions during the problem-solving process (Sapitri et al., 2016) The use of monopoly media makes a significant contribution to the research findings. Students can take on more active roles, make learning more enjoyable, and improve their memory by practicing many questions on question cards (Ravinah et al., 2019).

3. Hypothesis Testing

Based on the results of the normality test in Table 2, the learning outcomes have abnormal data. Therefore, to test the hypothesis, a non-parametric test, namely the Mann-Whitney U test, is used. The results of the Mann-Whitney U test are presented in Table 13 below.

Table 13. Mann Whitney U Test

Posttest-Pretest	Signifikansi	Keputusan Uji
Critical Thinking Skills	0.019	H_0 rejected
Learning Outcomes	0.041	H_0 rejected

Based on the results of the Mann-Whitney U test, shown in Table 13, significance values of 0.019 were obtained for the variable of critical thinking ability and 0.041 for learning outcomes. This value is less than the significance of probability (Sig), which is 0.05. Therefore, the null hypothesis is rejected. Thus, the results of the study indicate that the application of the discovery learning model, assisted by chemical monopoly, has a positive effect on critical thinking skills and cognitive learning outcomes.

The research results indicate that enhancing students' critical thinking skills has a positive impact on their learning outcomes. The learning outcomes indicated that 100% of students achieved at least one of the learning objectives in the experimental class. This achievement demonstrates that

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

students not only cognitively understand the material but also effectively connect concepts, analyze information, and draw conclusions. This aligns with the characteristics of discovery learning, which encourages students to actively engage in the process of discovering concepts. When students become accustomed to critical thinking, analyzing problems, concluding, and evaluating information, they gain a deeper understanding of the material. This deeper understanding is then reflected in improved learning outcomes. Thus, critical thinking skills are not only a goal but also a means to achieving optimal learning outcomes.

CONCLUSION

Based on the research results and discussion, it can be concluded that the discovery learning model, assisted by chemical monopoly, affects learning outcomes and critical thinking skills. This conclusion is supported by the significance values obtained from hypothesis tests using the Mann-Whitney U test, which were 0.019 and 0.041. Therefore, it is declared that H_0 is rejected, which means that there is an effect of using the discovery learning model assisted by chemical monopoly on critical thinking skills and learning outcomes. The experimental class experienced a higher increase compared to the control class in both critical thinking skills and cognitive learning outcomes.

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