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The Effect of the Discovery Learning Model Assisted by the Photomath Application on Students' Critical Thinking Skills in the Topic of Systems of Linear Equations in Two Variables (SPLDV)

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ABSTRACT

Many students still struggle to think critically when working on mathematics problems, and this difficulty is especially visible in the topic of Systems of Linear Equations in Two Variables (SPLDV). The purpose of this research was to examine whether Discovery Learning combined with the Photomath application influences students' critical thinking. A quasi-experimental quantitative design was adopted in the form of a Nonequivalent Pretest-Posttest Control Group Design. Participants were 38 eighth graders of SMP Negeri 3 Hutaraja Tinggi, chosen purposively and divided equally into an experimental group (n = 19) and a control group (n = 19). An essay test built on Facione's five critical thinking indicators served as the instrument, and the scores were examined through N-Gain and inferential statistics. The mean N-Gain reached 0.8004 (high) in the experimental group, compared with 0.3213 (medium) in the control group. The independent-samples t-test yielded t = 12.375, exceeding the critical value of 2.028, with $p = 0.000 < 0.05$; hence H_0 was rejected, while H_1 was supported. These findings show that Discovery Learning supported by Photomath has an effect on students' critical thinking on SPLDV.

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1. INTRODUCTION

Education plays a central role in raising the quality of human resources, since it equips people with the knowledge, attitudes, and competencies required to deal with the demands of life. According to Setiana and Purwoko [1], learning today is expected to go beyond content mastery and to cultivate higher-order abilities, including creativity, collaboration, communication, and critical thinking. Among these abilities, critical thinking has received particular attention in mathematics education. Ennis [2] characterises

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it as a rational and reflective way of thinking that guides a person in judging which claims to accept and which actions to take. Facione [3] breaks this ability down into five components: interpretation, analysis, evaluation, inference, and explanation. Similarly, Yani et al. [4] note that students' critical thinking can be seen in how they clarify a problem at a basic level, build supporting skills, reach conclusions, and plan the strategy and tactics for solving it. Clasrissa et al. [5], a study co-authored by Maysarah, likewise investigated critical thinking in the context of solving mathematical problems, while Siregar and Narpila [6] found that Problem-Based Learning had a measurable influence on students' mathematical critical thinking.

Mathematics contributes substantially to the growth of students' thinking, covering not only computation but also logical, systematic, analytical, and critical reasoning [7]. At the junior high school level, SPLDV is one of the topics that demands such reasoning. Problems in this topic are usually worked out by substitution or elimination [8]. When working on them, students must do more than calculate: they need to make sense of the problem, choose a suitable strategy, and describe each step of the solution in an orderly way. This agrees with evidence that particular instructional approaches can strengthen students' thinking competence and their capacity to handle higher-order thinking skills (HOTS) items [9].

In the field, however, students' critical thinking on SPLDV remains weak. A preliminary observation at SMP Negeri 3 Hutaraja Tinggi revealed that 87.5% of students scored below the minimum mastery criterion (KKM) of 70 on this topic, and only 12.5% met or surpassed it. This situation mirrors the broader picture of mathematics achievement in Indonesia. In PISA 2025, Indonesian students scored 364 in mathematics, two points lower than the 366 recorded in PISA 2022 and well under the OECD mean of 463 [10]. Such figures suggest that Indonesian students still need substantial support, especially on tasks that call for reasoning and problem solving.

Interviews with the mathematics teacher pointed to three likely causes of the weak critical thinking: instruction that is still dominated by the teacher, few opportunities for students to ask questions or take part in discussion, and limited use of technology in mathematics lessons. Edi and Rosnawati [11] reported a similar pattern, observing that teacher-dominated lessons leave students passive and give them little practice in thinking critically. Discovery Learning offers a way to tackle these problems because it places students at the centre of finding concepts through exploration and problem solving [12], [13]. This is in line with Bruner's [14] view that concepts are grasped more deeply when learners uncover them on their own through active inquiry. Batubara et al. [15] compared Discovery Learning and Problem-Based Learning with respect to students' critical thinking, and Kartika and Rakhmawati [16] found that Inquiry Learning raised students' mathematical critical thinking.

Besides choosing a suitable model, teachers can also draw on technology to enhance mathematics learning. Photomath is an application that many students already use; it presents worked solutions to mathematics problems in a detailed, step-by-step format [17]. Prior work indicates that the application helps students follow the process of solving mathematical problems in a clearer and more orderly manner [18]. For SPLDV

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specifically, Photomath can support students in understanding the solution procedure [19]. Its contribution to problem-solving ability tends to be positive when it is used properly, that is, to verify answers instead of supplying them instantly [20]. Even so, teacher supervision remains necessary, since students who treat the application as a shortcut may become dependent on it. Teachers therefore have to make sure that students think through, check, and reflect on the solutions rather than simply accepting what the application displays [21]. For this reason, the present study places Photomath at the verification stage only: students first work on each problem by themselves and afterwards compare their procedure and answer with the one Photomath produces.

Earlier studies have reported that Discovery Learning can raise students' critical thinking in mathematics [11] and that Photomath likewise has a positive influence on this ability [22]. In a systematic literature review, Rifa'i and Yahfizham [23] described Photomath as a supporting tool in mathematics learning. Other research has linked Photomath to better mathematical self-efficacy and stronger understanding of SPLDV [24], [19]. Recent work also shows that the critical thinking of junior high school students when facing HOTS problems is still a matter of concern [9]. Fatmawati and Siregar [25], who examined Game-Based Learning on the topic of flat-faced solid geometry, demonstrated that innovative models are worth exploring as a means of fostering critical thinking. Nevertheless, most of these studies treated the learning model and the instructional medium as separate variables. Studies that bring Discovery Learning and Photomath together in one learning process, especially on SPLDV in junior high school, are still scarce.

The urgency of this research stems from the need for mathematics instruction that is innovative and that uses technology appropriately to strengthen critical thinking. Through Discovery Learning, students have room to find concepts actively, examine information, and formulate conclusions, while Photomath can act as an aid that clarifies how a problem is solved. The application is meant to help students check and understand procedures, not to replace their own reasoning. Investigating Discovery Learning supported by Photomath is therefore worthwhile, as the combination is expected to produce active lessons that also nurture students' critical thinking on SPLDV.

Responding to this gap, the novelty of the study lies in combining Discovery Learning with Photomath, with the application acting as a supporting tool within the mathematics lesson. The combination is intended to give students experiences in which they uncover concepts, work on problems, and examine and judge solution procedures in a more orderly way. In other words, technology is not treated merely as a means of getting answers but as part of a learning process directed at building the critical thinking of eighth graders on SPLDV. Accordingly, the study sets out to examine whether Discovery Learning supported by Photomath influences the SPLDV critical thinking of eighth-grade students at SMP Negeri 3 Hutaraja Tinggi.

2. METHOD

A quantitative approach was taken, using a quasi-experimental design. Specifically, the study followed the Nonequivalent Pretest-Posttest Control Group Design, in which two

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intact classes, one experimental and one control, are compared without randomly assigning individual students. Both classes sat a pretest and a posttest, but only the experimental class received the intervention [26].

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Data collection took place at SMP Negeri 3 Hutaraja Tinggi in the odd semester of the 2026/2027 school year. All eighth graders, spread over four classes (VIII-1 to VIII-4), made up the population. Two classes were chosen by purposive sampling on the advice of the mathematics teacher: VIII-1 became the experimental class and VIII-2 the control class. With 19 students in each, the sample comprised 38 students in total. Purposive sampling was used because the classes were selected according to particular considerations that matched the aims of the study [27].

Discovery Learning supported by Photomath was the independent variable, and students' critical thinking on SPLDV was the dependent variable. Lessons in the experimental class went through the six phases of Discovery Learning: stimulation, problem statement, data collection, data processing, verification, and generalization. During verification, students opened Photomath to compare and check the procedures they had already worked out on their own. The control class, in contrast, was taught conventionally, with the teacher explaining the material, demonstrating examples, and assigning practice problems.

Critical thinking was measured with an essay test that served as both pretest and posttest in the two classes. The test consisted of two main items, each divided into five parts, giving ten sub-items altogether. Its construction was guided by the five critical thinking indicators proposed by Facione, namely interpretation, analysis, explanation, evaluation, and inference [3]. Every sub-item was marked on a 0–4 rubric, so the highest possible raw score was 40. Because an instrument is the means of gathering information on students' abilities, its quality needs to be established through trials before it is used for research [28].

The test was first tried out with ninth graders who had already learned SPLDV. The trial examined validity, reliability, item difficulty, and discriminating power. For validity, every one of the ten sub-items produced an r-count above the r-table value of 0.396, so all were judged valid. Cronbach's Alpha reached 0.866, indicating very high reliability. In terms of difficulty, four sub-items were easy and six were moderate. As for discriminating power, one sub-item was rated excellent and the other nine good. On these grounds, every sub-item was deemed appropriate for use in the study.

SPSS 27 was used for all analyses. Descriptive statistics summarised the minimum, maximum, mean, and standard deviation of the scores. Next, the assumptions were checked: normality through the Shapiro-Wilk test and homogeneity through Levene's test. Once both assumptions were satisfied, the hypothesis was tested with an independent-

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samples t-test ($\alpha = 0.05$) to compare the critical thinking results of the experimental and control classes [29].

3. RESULTS AND DISCUSSION

3.1. Research Result

Two classes at SMP Negeri 3 Hutaraja Tinggi took part as samples, an experimental class and a control class with 19 students each. The former learned through Discovery Learning supported by Photomath, whereas the latter followed conventional lessons. Pretest and posttest scores were processed with descriptive statistics, assumption tests, and hypothesis testing, all carried out in SPSS 27.

3.1.1. Descriptive Statistics

Descriptive analysis was used to describe students' critical thinking in both classes before and after the intervention. Table 2 summarises the results.

Table 2. Descriptive Statistics of Critical Thinking Scores

Group	Stage	N	Min	Max	Mean	SD
Experimental	Pretest	19	20	45	33.79	7.864
Experimental	Posttest	19	65	100	85.79	10.937
Control	Pretest	19	18	43	28.63	6.175
Control	Posttest	19	38	73	51.26	9.285

Source: Primary data (SPSS 27 output).

As Table 2 shows, pretest scores in the experimental class lay between 20 and 45 (M = 33.79, SD = 7.864). After being taught with Discovery Learning and Photomath, the same class obtained posttest scores between 65 and 100 (M = 85.79, SD = 10.937). The control class had pretest scores from 18 to 43 (M = 28.63, SD = 6.175) and posttest scores from 38 to 73 (M = 51.26, SD = 9.285). The experimental class's mean therefore rose by 52.00 points, from 33.79 to 85.79, whereas the control class's mean rose by 22.63 points, from 28.63 to 51.26. Descriptively, then, the gain in critical thinking was larger in the experimental class.

3.1.2. Analysis of the Improvement in Critical Thinking Skills (N-Gain)

To gauge how much students' critical thinking grew from pretest to posttest, N-Gain was calculated for each group. Table 3 lists the outcomes.

Table 3. Mean N-Gain of Both Classes

Group	Number of Students	Mean N-Gain	Category
Experimental	19	0.8004	High
Control	19	0.3213	Medium

Table 3 indicates a mean N-Gain of 0.8004 for the experimental class, placing it in the high category, and 0.3213 for the control class, placing it in the moderate category. Critical thinking thus grew considerably more among experimental students than among control students.

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3.1.3. Prerequisite Test Analysis

Before testing the hypothesis, the N-Gain data of both classes were checked for normality and homogeneity. Since each class had only 19 students, normality was examined with the Shapiro-Wilk test, whose output appears in Table 4.

Table 4. Shapiro-Wilk Test on N-Gain Data

Tests of Normality				
	Group	Shapiro Wilk		
N-Gain		Statistic	df	Sig.
	Experimental	0.934	19	0.206
	Control	0.986	19	0.989

Source: Primary data (SPSS 27 output).

Table 4 shows Shapiro-Wilk significance values of 0.206 for the experimental class and 0.989 for the control class. As both exceed 0.05, the N-Gain data in each class can be regarded as normally distributed.

Equality of variances between the two classes was then examined with Levene's test, as reported in Table 5.

Table 5. Levene's Test on N-Gain Data

Tests of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
Ngain_Score	Based on Mean	3.016	1	36	0.091
	Based on Median	2.602	1	36	0.115
	Based on Median and with adjusted df	2.602	1	32.834	0.116
	Based on trimmed mean	3.040	1	36	0.090

Source: Primary data (SPSS 27 output).

In Table 5, the significance value based on the mean is 0.091, which is above 0.05, meaning the two classes have equal variances in their N-Gain data. With normality and homogeneity both met, the independent-samples t-test was appropriate for testing the hypothesis.

3.1.4. Hypothesis Testing

Given that the critical thinking data came from normally distributed populations with equal variances, the hypothesis was tested using an independent-samples t-test at $\alpha = 0.05$. The purpose of this test was to establish whether the two classes differed in critical thinking. Table 6 displays the output.

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Table 6. Independent-Samples t-Test on N-Gain Data

Independent Samples Test				
		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
N-Gain Score	Equal variances assumed	12.375	36	0.000

Source: Primary data (SPSS 27 output).

According to Table 6, the two-tailed significance is 0.000, below 0.05, and the computed t of 12.375 exceeds the critical t of 2.028. Consequently, H_0 is rejected and H_1 is accepted, meaning that critical thinking differed significantly between the experimental and control classes. It follows that Discovery Learning supported by Photomath has a significant influence on students' critical thinking on SPLDV.

3.1.5. Analysis of Improvements in Critical Thinking Skills Based on Indicators

To see how far each aspect of critical thinking improved after the Discovery Learning–Photomath lessons, an indicator-level analysis was carried out. It covered Facione's [3] five indicators: interpretation, analysis, explanation, evaluation, and inference. For every indicator, N-Gain was computed separately for the experimental and control classes, as shown in Table 7.

Table 7. Indicator-Level N-Gain of Critical Thinking

No.	Indicator	Experimental Class	Category	Control Class	Category
1	Interpretation	0.9474	High	0.4674	Moderate
2	Analysis	0.8667	High	0.3325	Moderate
3	Explanation	0.8465	High	0.3140	Moderate
4	Evaluation	0.8342	High	0.2444	Low
5	Inference	0.6018	Moderate	0.2566	Low

Source: Research data (critical thinking test results).

For an easier visual comparison between the classes, the indicator-level N-Gain values in Table 7 are also plotted as a bar chart in Figure 1.

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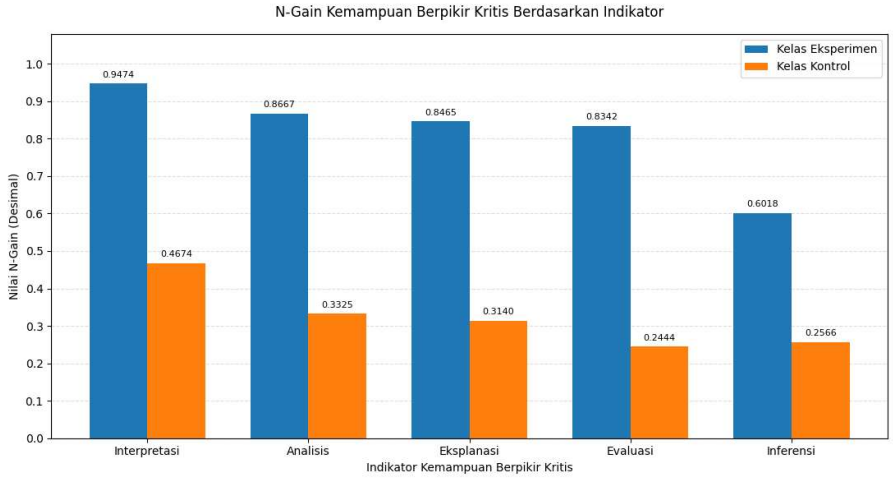


Figure 1. Indicator-Level N-Gain of Critical Thinking in Both Classes

Table 7 and Figure 1 make clear that the experimental class outperformed the control class on every indicator. Within the experimental class, interpretation recorded the largest N-Gain (0.9474, high) and inference the smallest (0.6018, moderate). In the control class, interpretation was likewise the highest (0.4674, moderate), while evaluation was the lowest (0.2444, low).

This pattern shows that experimental students surpassed control students on all indicators. It is consistent with the way the Discovery Learning phases prompt students to make sense of a problem, pick out relevant information, work with data, explain their procedure, confirm whether their answer is correct, and arrive at a conclusion. Photomath added to this by allowing students to check and compare their own solutions independently.

3.2. Discussion

The aim of this research was to examine how Discovery Learning supported by Photomath influences students' critical thinking on SPLDV. The findings reveal that students taught with this combination improved their critical thinking differently from students who received conventional teaching.

Descriptively, the experimental and control classes started with pretest means of 33.79 and 28.63, respectively. Following the intervention, the experimental mean climbed to 85.79, while the control mean reached 51.26, so the experimental class gained more.

N-Gain analysis confirmed this picture: the experimental class achieved 0.8004 (high) and the control class 0.3213 (moderate). Students who learned through Discovery Learning with Photomath therefore developed their critical thinking to a greater extent than their peers in the control class.

Growth can also be traced through the five indicators assessed, namely interpretation, analysis, explanation, evaluation, and inference. On every indicator, the experimental class showed a higher N-Gain than the control class. This advantage is attributed to the six Discovery Learning phases (stimulation, problem statement, data

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collection, data processing, verification, and generalization), with Photomath serving as a means for students to check and assess their own solutions.

On interpretation, N-Gain was 0.9474 in the experimental class and 0.4674 in the control class. Experimental students thus became better at grasping a problem, recognising the known information, and identifying what had to be found. The stimulation and problem statement phases appear to underlie this gain. In stimulation, the teacher opened with everyday contextual problems to spark curiosity. In the problem statement phase, students were directed to list the known facts, specify the question, and frame the problem in an orderly way. These activities accustomed students to understanding an SPLDV problem before choosing how to solve it.

On analysis, the experimental class reached 0.8667 and the control class 0.3325. Experimental students improved more in linking pieces of information and choosing a fitting solution strategy. This gain is tied to the problem statement, data collection, and data processing phases. In the first of these, students looked for connections among the facts in the problem. In data collection, they gathered information from reading materials and group discussion. In data processing, they used that information to build mathematical models and to decide whether substitution or elimination was the better method for the SPLDV problem at hand. As a result, students did not stop at getting an answer; they also understood how the variables were related and why a particular method was chosen.

On explanation, N-Gain was 0.8465 for the experimental class versus 0.3140 for the control class. Experimental students became more capable of describing their solution process and the reasoning behind it. This skill was cultivated mainly in the data processing phase, where students worked through SPLDV problems step by step in groups using the student worksheets (LKPD). They were prompted to describe how they set up the mathematical model, why they opted for substitution or elimination, and what steps led to their answer. Group discussion and class presentations further gave students chances to convey their reasoning in an orderly manner and to be accountable for their solutions.

On evaluation, the experimental class obtained 0.8342 and the control class 0.2444. Experimental students grew more skilled at judging whether a solution process and its result were correct. This gain is linked to the verification phase, in which students re-examined the answers they had produced on their own against the procedure shown by Photomath. Using the step-by-step feature, they could see whether the steps were consistent, spot possible mistakes, and judge the correctness of their work. Photomath thus functioned as a checking tool that helped students assess their own work, not as a way to obtain ready-made answers while skipping the thinking.

On inference, N-Gain was 0.6018 in the experimental class and 0.2566 in the control class. Experimental students thus improved more in reaching conclusions from the given information and from their solutions. This is connected to the generalization phase, during which students were guided to conclude from their SPLDV solutions and to relate the numerical results back to the contextual problem. Having checked their work in the verification phase, they could rely on the confirmed results when stating their conclusions. Still, inference had the smallest N-Gain of the five indicators in the experimental class,

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suggesting that students' skill in drawing conclusions, especially in connecting calculations to the problem context, needs further strengthening.

Taken together, the N-Gain results show that the experimental class improved more than the control class on all indicators examined. This improvement was supported by the six phases of Discovery Learning, which allowed students to understand problems, identify information, gather and process data, verify their results, and conclude. Photomath contributed mostly during verification, when students set their own procedures side by side with those generated by the application. The combination therefore offered a learning experience in which students actively found concepts, solved problems, and assessed their own work, which in turn strengthened their critical thinking on SPLDV.

Whether the difference in improvement was statistically meaningful was examined after checking the assumptions on both classes' N-Gain data. The Shapiro-Wilk test produced significance values of 0.206 (experimental) and 0.989 (control), both above 0.05, so the data were normal. Levene's test gave a significance of 0.091, also above 0.05, so the variances were equal.

The independent-samples t-test then produced a t-count of 12.375 against a t-table of 2.028, with a significance of 0.000 (< 0.05). H_0 was consequently rejected in favour of H_1, confirming that Discovery Learning supported by Photomath influences students' critical thinking on SPLDV.

These outcomes agree with Edi and Rosnawati [11], who investigated students' critical thinking in mathematics lessons based on Discovery Learning. Their work presents Discovery Learning as a model that draws students into actively finding and making sense of mathematical concepts. What the two studies share is the use of Discovery Learning to foster critical thinking. Siregar and Andhany [30] likewise found that models which actively involve students can raise their critical thinking. This matches the present result that the experimental and control classes differed in critical thinking after receiving different treatments. The current study therefore adds to the evidence that student-centred models built on active participation help develop both critical thinking and mathematical problem solving.

Rokan, Maharani, and Lubis [24] also studied Discovery Learning combined with Photomath, but they looked at its effect on students' mathematical self-efficacy. Although their outcome variable was different, their study resembles the present one in employing Photomath as a supporting tool within Discovery Learning. The present research extends that line of work by examining the same combination with respect to critical thinking, specifically on SPLDV.

Overall, Discovery Learning supported by Photomath influences students' critical thinking. Discovery Learning pushes students to find and construct understanding by themselves, while Photomath lets them check and appraise how they solved a problem. Together, the two components help students not only arrive at answers but also understand, analyse, explain, evaluate, and draw conclusions from their SPLDV solutions.

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4. CONCLUSION

The findings lead to the conclusion that Discovery Learning supported by Photomath has a significant influence on students' critical thinking on SPLDV. Evidence for this comes from the independent-samples t-test on N-Gain scores, which gave a t-count of 12.375, larger than the t-table value of 2.028, with a significance of 0.000 < 0.05; hence H_0 was rejected in favour of H_1. The experimental class also attained a mean N-Gain of 0.8004 (high), exceeding the control class's 0.3213 (moderate). Gains appeared on all five critical thinking indicators, namely interpretation, analysis, explanation, evaluation, and inference, and on each of them the experimental class progressed further than the control class. Discovery Learning supported by Photomath can therefore be considered an alternative instructional approach for fostering students' critical thinking in mathematics, particularly on SPLDV.

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