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THE APPLICATION OF THE FLIPPED CLASSROOM MODEL TO IMPROVE CRITICAL THINKING SKILLS OF 8TH GRADE STUDENTS ON LINEAR INEQUALITIES IN ONE VARIABLE

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Abstract. Critical thinking skills of junior high school students in mathematics, particularly in Linear Inequalities in One Variable (LIOV), remain in the low category because students often follow mechanical procedures without in-depth analysis. This study aims to examine whether the application of the flipped classroom model can improve students' critical thinking skills specifically in LIOV material. This quantitative study employed a quasi-experimental nonequivalent control group design involving 60 eighth-grade students in West Bandung Regency, divided into experimental and control groups. Data were collected using an essay-type critical thinking test and observation sheets, then analyzed using N-Gain scores and the Mann-Whitney U test. The results showed that the average N-Gain for the experimental group (0.680) was significantly higher than the control group (0.319), with a significance value of 0.000. The study concludes that the flipped classroom model is effective in improving critical thinking skills in LIOV through structured phases of independent exploration and collaborative in-class activities. This research implies that the flipped classroom model serves as a relevant instructional alternative to foster higher-order thinking skills and systematic problem-solving in mathematics education.

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INTRODUCTION

Science and technology are currently developing at a rapid pace, requiring the field of education to keep up with and anticipate these changes. Consequently, education must prepare students to adapt to advancements in science and technology. One field closely related to the development of science and technology is mathematics since laws in sciences and technology are usually expressed in mathematical equations. Through mathematics education, students are expected to master several mathematical skills, which will contribute to their mastery of science and technology.

One of the most important mathematical skills today is critical thinking. According to Ennis (1996) and Adhikari et al. (2025), critical thinking is a process involving reflection and focusing on making correct and appropriate decisions. This indicates that this skill plays a crucial role in mastering mathematics, which in turn influences the mastery of science and technology, as it serves as the primary foundation for understanding across various disciplines.

Specifically, Rahmaini & Ogylva (2024) explain that in the context of mathematics learning, critical thinking is not limited to solving computational procedures but also involves analyzing information, evaluating arguments, and drawing logical conclusions from given problems. In line with the research by Rahmaini & Ogylva (2024), Syafril et al. (2020) demonstrate that critical thinking skills hold a significant value for students, as they support rational decisions and logical conclusions that students can apply in the field of mathematics. Furthermore, in daily life, critical thinking skills are essential for accurately analyzing information and solving problems systematically and logically (Trúsiková & Klára, 2022).

In reality, students' critical thinking skills in mathematics learning still face challenges. Several studies indicate that the critical thinking skills of junior high school students remain in the low category. Findings from a study conducted by Mirza et al. (2024) reveal that a common

difficulty student's face in understanding inequality concepts stems from their tendency to analogize the rules of ordinary linear equations, causing them to forget to change the inequality sign when multiplying or dividing by negative numbers. Their difficulty in understanding the concept of inequality signs is attributed to low critical thinking skills. Consequently, they tend to follow mechanical procedures without in-depth analysis or logical evaluation. Furthermore, Kusumawati et al. (2022) add that students' critical thinking skills are hindered, as evidenced by their difficulty in providing logical reasons and drawing conclusions because mathematics learning remains procedural in nature. On the other hand, Rochmad et al. (2021) found that many students do not verify their answers or check for possible errors, often resulting in incorrect and incomplete solutions. This habit of not verifying answers is generally influenced by a lack of critical thinking and problem-solving skills.

Linear inequalities are a mathematical topic that is often considered abstract, requiring strong critical thinking skills to understand. This topic requires a solid grasp of algebraic concepts to model relationships between quantities across various scientific disciplines. In the learning process, students are required to analyze information, interpret relationships between variables, and determine the correct solution, all of which help develop students' critical thinking skills (Yunita et al., 2026).

However, some students today still struggle to understand algebraic concepts, which impacts their mastery of inequalities. In this regard, Azuhra et al. (2025) found that students often fail to change the inequality sign when multiplying or dividing both sides. This is because students merely memorize procedures without conceptual understanding linear inequalities consist of basic concepts such as the use of inequality symbols and an understanding of first-degree variables.

In particular, the linear inequalities in one variable (LIOV) material plays a crucial role in developing students' critical thinking skills because this topic requires the ability to analyze information, interpret relationships between variables, and determine the correct solution (Yunita et al., 2026). This is why LIOV is an important topic to be taught at the junior high school level, serving as a foundation for understanding the concepts of functions, quadratic inequalities, and contextual problem-solving. Fundamentally, LIOV discusses the inequality relationship between two linear forms containing only one variable raised to the first power and denoted by an inequality sign (Puum et al., 2022).

Regarding learning outcomes in LIOV, Margita & Berahman (2025) report that a majority of junior high school students still exhibit low proficiency in solving word problems within the LIOV curriculum. In this context, students struggle with understanding the given problems, formulating mathematical models, and verifying their work solutions. Similar findings were reported by Umam & Susandi (2022), who noted that common student errors in LIOV material occur during the interpretation and calculation steps, particularly when problems are contextual or non-routine.

One approach to enhancing middle school students' critical thinking skills in the LIOV curriculum is through the implementation of innovative instructional models that enable students to actively engage in the learning process. According to Latifah et al. (2024), the flipped classroom model is an innovative and participatory instructional approach that encourages students to be active and independent learners while enhancing their critical thinking skills. The flipped classroom model is a learning model that reverses the order of the learning process. According to Bergmann & Sams (2023), the flipped classroom is a learning model that swaps the roles of learning activities between home and school. In the conventional learning model, students receive instruction in class and then complete homework at home, whereas in the flipped classroom model, students first study the material independently outside of class through videos, modules, or digital learning materials provided by the teacher, and then use class time for discussion and to reinforce conceptual understanding. According to Nurjannah et al. (2022), mathematics instruction using the flipped classroom model has proven effective in enhancing students' critical thinking skills.

In a similar vein, research conducted by Nasution et al. (2021) on junior high school students concluded that the implementation of the flipped classroom model significantly

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contributes to improved mathematics learning outcomes, as students have prepared themselves before face-to-face instruction begins. Meanwhile, Syajili & Abadi (2021) demonstrated in their study that the flipped classroom can enhance students' learning autonomy, as students become accustomed to accessing and understanding the material before class begins. However, to date, there have been few studies specifically examining students' critical thinking skills in LIOV material using the flipped classroom model, namely Puspita et al. (2023), but their study is qualitative in nature and the topic is about social science using participants from elementary school.

Based on a review of previous research, there is a significant opportunity to explore the application of the flipped classroom model in LIOV material. Therefore, this study examines whether the application of the flipped classroom model can improve students' critical thinking skills in LIOV material.

RESEARCH METHODS

This study employed a quantitative approach using a quasi-experimental design of the nonequivalent control group type. This design involved two groups, the experimental group, which received the flipped classroom model, and the control group, which received the conventional learning model. In the control group, learning was conducted using a conventional model with a teacher-centered approach. All delivery of basic material and example questions was conducted entirely in the classroom without any introductory material (pre-class). A quasi-experimental design was chosen because the researcher did not fully randomize the subjects (Borg & Gall, 2003). This study was conducted at a junior high school located in West Bandung Regency, West Java Province. The study population comprised all eighth-grade students at the school during the second semester of the 2025/2026 academic year. The sample was selected using purposive sampling, taking into account the equivalence of student characteristics and learning conditions with the research objectives (Borg & Gall, 2003).

According to Sugiyono (2019), data collection is the process of obtaining empirical information from research subjects used to answer research questions and test hypotheses. In this study, several data collection techniques were used, including a critical thinking skills test and observation. This critical thinking skills test was designed to measure and assess students' critical thinking abilities regarding the LIOV material. The test consists of essay-type questions based on five indicators of critical thinking. Observations were then conducted to monitor the implementation of teaching and learning activities in both the experimental and control groups. Observations were used to ensure that the treatment administered proceeded in accordance with the established instructional design.

The research instruments used in this study consist of test and non-test instruments. According to Sugiyono (2019), instruments must be developed based on indicators relevant to the research variables to ensure the results possess scientific validity. The test instrument consists of critical thinking questions on the LIOV material, developed based on critical thinking indicators. The test instruments used in this study met the quality criteria for research instruments. Through the expert validation stage, the instruments were deemed suitable in terms of content, construct, and language. Furthermore, through empirical validity and reliability testing, the instrument was proven to have high accuracy and consistency, enabling it to objectively measure students' critical thinking skills regarding LIOV material. In this study, the critical thinking skills indicators used are in line with the context of mathematics learning described by Facione (2011) as shown in Table 1.

Test data were obtained from the pretest and posttest results of students' critical thinking skills on the LIOV material. Before being used in the study, the test instrument was first validated to ensure that each item could measure critical thinking skills in accordance with the predetermined indicators. After the instrument was deemed valid, the pretest and posttest data were then analyzed further. Before calculating the increase in critical thinking skills using N-Gain, the data were first tested for normality and homogeneity. The normality test was conducted to determine whether the data were normally distributed, while the homogeneity test was

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conducted to determine the equality of variances between the research groups. Next, the N-Gain scores between the experimental and control groups were compared to identify differences in the improvement of critical thinking skills between students using the flipped classroom model and those using the conventional learning model. According to Hake (1998), N-Gain is a measure of learning outcomes normalized against the maximum score that can be achieved.

Table 1. Indicators of Critical Thinking Skills

No	Aspect	Indicator
1	Interpretation	At this stage, students read and understand the context and data provided in the problem. Students must be able to identify what is known, what is being asked, and then transform that information into relevant mathematical symbols, variables, equations or diagrams.
2.	Analysis	After students have modeled a problem, in this stage they analyze the model. Students are asked to connect the necessary concepts and determine the most efficient and effective steps or formulas to reach a solution.
3.	Inference or Conclusion	After obtaining the mathematical results, students must reinterpret them within the context of the original problem to answer the questions posed.
4.	Evaluation	At this stage, students must review the entire process they have followed. Evaluation also includes checking the accuracy of calculations, the validity of the mathematical model used, and whether the final answer is logical within the context of the problem.
5.	Explanation	At this stage, students demonstrate the ability to present the entire problem-solving process from understanding to conclusion in a structured, clear manner using correct mathematical notation.

RESULTS AND DISCUSSION

The study was conducted in a conducive environment, with students able to follow the learning flow in an orderly manner and demonstrating good readiness to learn. The experimental and control groups each received 5 (five) sessions, each lasting 2 hours of instruction or 80 minutes. The first session began with the administration of a pretest to the students. Subsequently, classroom instruction was conducted over three consecutive sessions. Then, in the final session the fifth session students were given a posttest to measure critical thinking skills in both classes.

One of the main stages in implementing the flipped classroom model was the pre-class stage, which was the preparation phase conducted before face-to-face instruction took place. During this stage, students were guided to study the material in advance as foundational knowledge before participating in classroom learning activities. In the pre-class stage for the flipped classroom model, students were asked to study the LIOV material independently before face-to-face instruction begins. Students were directed to watch instructional videos first and review the worksheets that would be discussed during in-class learning activities.

Subsequent in-class learning is focused on worksheet activities as a means to deepen conceptual understanding and strengthen students' thinking processes. The worksheets students completed consisted of a warm-up phase section, problem-solving exercises for comprehension, application, and drawing conclusions. Through these worksheets, students systematically worked through problems, discussed solution steps, and drew conclusions based on the results of problem interpretation and analysis they had conducted.

The use of N-Gain (normalized gain) is to determine the relative improvement of each student by considering their initial critical thinking ability (pretest) and their critical thinking ability (posttest). Additionally, N-Gain can provide an evaluation regarding the effectiveness of implementing a learning model. The descriptive statistical data for the N-Gain index is presented in Table 2.

N-Gain scores for each student were calculated using Microsoft Excel. Based on Table 2 below, it is evident that the average N-Gain for critical thinking skills among students in the experimental group is higher than that of the control group. The average N-Gain for the experimental group is 0.680, while the average N-Gain for the control group is 0.319.

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Table 2. Descriptive Statistics of N-Gain Data for Critical Thinking Skills of Students in the Experimental Group and Control Group

Statistical Data	Experimental Group	Control Group
Number of Students	30	30
Average	0.680	0.319
Standard Deviation	0.182	0.238
Maximum Value	1.00	0.75
Minimum Value	0.35	0.02
Maximum Possible Score	1.00	

The standard deviation of the N-Gain for the experimental group, at 0.182, is smaller than that of the control group, which has a standard deviation of 0.238; thus, the variation in the improvement of critical thinking skills in the control group is greater. Furthermore, the N-Gain in the experimental group had a maximum value of 1.00 and a minimum value of 0.35, with a range of 0.65. Meanwhile, the N-Gain in the control group had a maximum value of 0.75 and a minimum value of 0.02, resulting in a range of 0.73.

Descriptively, these results indicate that the improvement (N-Gain) in students' critical thinking skills in the experimental group was relatively higher and more evenly distributed compared to the control group. To determine whether this difference was statistically significant, an inferential statistical test was subsequently conducted using IBM SPSS Statistics software.

The normality test for the N-Gain data on students' critical thinking skills in the experimental and control groupes was conducted using the Shapiro-Wilk test because the sample size (N) was less than or equal to 50. The decision criterion is:

If the Sig. (p-value) $< \alpha = 0,05$, then the null hypothesis ($H0$) is rejected

If the Sig. (p-value) is $\geq \alpha = 0,05$, then the null hypothesis ($H0$) is accepted

Table 3 shows the results of the normality test for the N-Gain data of the experimental and control groupes regarding students' critical thinking skills.

Table 3. Results of the Normality Test for Students' Critical Thinking Ability N-Gain in the Experimental Group and Control Group

Class	Shapiro-Wilk			Decision
	Statistic	Df	Sig.	
Experimental group	0.947	30	0.138	$H0$ accepted
Control group	0.898	30	0.007	$H0$ rejected

Based on the normality test in Table 3 it was found that the significance value in the experimental group was 0.138, which is greater than the significance level of 0.05. Thus, the decision made was to accept the null hypothesis ($H0$), meaning that the N-Gain data for students' critical thinking skills in the experimental group is normally distributed. Meanwhile, the significance value for the control group is 0.007, which is smaller than the significance level of 0.05. The decision made is to reject the null hypothesis ($H0$), so the N-Gain data for students' critical thinking skills in the control group are not normally distributed.

The results of the normality test show that only the experimental group is normally distributed, while the control group is not; therefore, the requirement for using a parametric test the independent t-test is not met. Consequently, the analysis of the difference in N-Gain between the two classes was conducted using the nonparametric Mann-Whitney U test, which does not require data to be normally distributed and is suitable for comparing two independent groups with different distribution characteristics.

The testing criteria used are as follows.

If the Sig. (p-value) is $\geq \alpha = 0,05$, then the null hypothesis ($H0$) is accepted.

If the Sig. (p-value) is$< \alpha = 0,05$, then the null hypothesis ($H0$) is rejected.

The results of the test of the difference in the mean N-Gain of students' critical thinking skills in the experimental and control group are presented in Table 4.

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Table 4. Results of the Test of the Difference in Mean N-Gain of Students' Critical Thinking Skills in the Experimental Group and Control Group

Class	Mean Rank	Mann-Whitney U	Sig. (2-tailed)
Experimental Class	41.98	105.50	0.000
Control group	19.02		

Table 4 shows that the mean rank of the experimental group, 41.98, is higher than that of the control group, 19.02. This difference in mean ranks indicates that the improvement in students' critical thinking skills in the experimental group is greater than in the control group. The Mann-Whitney U value is 105.50 with a Sig. (2-tailed) value of 0.000. Since the research hypothesis states that the increase in students' critical thinking skills in the experimental group is significantly higher than that in the control group, a one-tailed test was used.

The Sig. (1-tailed) value was derived by dividing the Sig. (2-tailed) value (1/2 × 0,000) by two. This Sig. (1-tailed) value is smaller than the significance level of 0.05; therefore, the decision made is to reject the null hypothesis ($H0$). Thus, it can be concluded that the increase in the N-Gain of critical thinking skills among students in the experimental group using the flipped classroom model is higher than that of students in the control group using the conventional learning model.

The improvement in critical thinking skills among students exposed to the flipped classroom model yielded better results compared to those using the conventional model. Descriptively, the N-Gain data indicate that the experimental group demonstrated a higher and more consistent increase. This indicates that the flipped classroom model can have a significant impact on strengthening the development of students' critical thinking skills. This aligns with research conducted by Zaeni et al. (2025), which revealed that the implementation of the flipped classroom model can accommodate the diversity of critical thinking abilities. Furthermore, Supriyadi et al. (2024) reinforce these findings by demonstrating that the flipped classroom model builds students' critical thinking skills through two integrated stages: independent learning via videos and modules at home, and in-depth exploration of the material through collaborative discussions and clarifications in class. This dual-environment approach creates a more active and reflective learning experience, resulting in better development of students' critical thinking skills compared to conventional learning models.

These positive findings are closely tied to the characteristics of the flipped classroom model, which provides students with the opportunity to explore the material in advance through videos, modules, worksheets, or practice problems during the pre-class phase. During this phase, teachers provide initial guidance in the form of additional explanations, thought-provoking questions, and critical inquiries. This gradual support helps students grasp foundational concepts before entering face-to-face classroom instruction. This makes students more cognitively prepared, allowing the critical thinking process to function more effectively during classroom activities. In line with this, previous research suggests that providing scaffolding during the pre-class phase can enhance students' cognitive readiness for higher-order thinking and tackling more complex tasks (Fajriani et al., 2021). Furthermore, Paralikar et al. (2022) revealed that the pre-class stage in the flipped classroom model fundamentally helps students recall facts and understand basic concepts (Lower-Order Cognitive Skills), so that time in class can be used to master the application of concepts and analyze them critically (Higher-Order Cognitive Skills).

In-class activities in flipped classroom learning allow teachers to focus on critical discussions, problem-solving, and reflective thinking activities. During this phase, students receive ongoing support in the form of strategic guidance, conceptual clarification, examples of reasoning, and critical argumentative questions. This support provides students with the opportunity to develop their ability to analyze information, identify problems, and evaluate arguments. This interactive process is a significant contributor to the improvement of students' critical thinking skills. This aligns with the findings of Safitri et al. (2025) that scaffolding in classroom discussions helps students structure their thinking and improve the quality of their arguments. Furthermore, Suwardika et al. (2024) revealed that the implementation of the flipped classroom model allows teachers to focus in-class activities on higher-order thinking tasks such

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as critical discussion and problem-solving, while students receive ongoing support in the form of guidance and conceptual clarification from the teacher. The research by Suwardika et al. (2024) empirically demonstrates that a student-centered in-class learning structure, with intensive teacher guidance, can improve students' abilities in interpretation, analysis, inference, evaluation, and explanation all of which align with the indicators of critical thinking skills.

The results of the normality test and the N-Gain difference support the conclusion that the flipped classroom model provides a more significant improvement compared to the conventional learning model. This difference illustrates that the flipped classroom model not only changes the sequence of student learning but truly serves as a platform that facilitates the enhancement of critical thinking through active, collaborative, and purposeful learning experiences. The post-class phase also plays a crucial role, as students can be guided to reflect on the thinking processes and strategies they have employed. During this phase, reflection is facilitated through feedback, evaluative questions, and alternative solution examples. This activity has proven to help students reassess their logical reasoning and address weaknesses in their reasoning. This aligns with research conducted by Tomesko et al. (2022), which found that guided reflection after class can enhance critical thinking skills and enable teachers to assess student learning outcomes.

Overall, the significant increase in N-Gain in the experimental group compared to the control group demonstrates that the flipped classroom is an effective learning model for enhancing students' critical thinking skills. The learning process, which gives students the opportunity to construct knowledge independently and then deepen it through gradual discussion, makes learning more meaningful, focused, and fosters the development of higher-order thinking skills. These findings are supported by Rahmatika et al. (2024), who analyzed 23 research articles on the impact of the flipped classroom model on critical thinking skills. The results consistently show that the flipped classroom model has a positive impact on improving students' critical thinking skills, due to a learning structure that allows students to build knowledge independently first before deepening it through collaborative activities in class. Thus, the flipped classroom model has been proven to enhance students' critical thinking skills through a structured learning process, ranging from independent exploration in the pre-class stage, critical deepening in the in-class stage, to evaluative reflection in the post-class stage.

CONCLUSIONS AND SUGGESTIONS

Based on the research findings and data analysis conducted, it can be concluded that the implementation of the flipped classroom model can improve the critical thinking skills of eighth-grade students in the subject of Linear Inequalities in One Variable (LIOV). This is demonstrated by the higher and more consistent N-Gain scores in the experimental group compared to the control group and supported by statistical test results showing a significant difference in improvement between the two groups. Thus, the flipped classroom model has proven effective in facilitating the systematic and sustainable development of students' critical thinking skills. This model is relevant for application in mathematics education as well as other subjects that require high-level analytical, evaluative, and reasoning skills.

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