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Integrating Comprehensive Mathematics Instruction into Google Classroom: Effects on Students' Mathematical Critical Thinking and Self-Efficacy

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Abstract: Indonesian students' mathematics performance remains below the OECD average, particularly on items requiring reasoning, interpretation of data, and problem-solving in real-world contexts. Although PISA outcomes are influenced by multiple factors, including curriculum alignment, learning opportunities, and socioeconomic conditions, prior studies indicate that students' difficulties with non-routine, reasoning-based tasks reflect limitations in higher-order mathematical thinking. In this context, strengthening students' mathematical critical thinking remains an urgent instructional challenge. This study aimed to determine whether students' mathematical critical thinking skills improved more significantly after using a Google Classroom-based Comprehensive Mathematics Instruction (CMI) model than after regular learning. Additionally, this research examined changes in students' mathematics self-efficacy before and after the intervention and explored the relationship between mathematical critical thinking skills and mathematics self-efficacy. A quasi-experimental nonequivalent control group design was employed. The population consisted of all tenth-grade students at SMAN 1 Jalancagak, with a purposive sample of 70 students drawn from two classes (X-10 and X-9). Data were collected using a mathematical critical thinking test and a mathematics self-efficacy questionnaire. The results show that students using the Google Classroom-based CMI model achieved significantly greater improvements in mathematical critical thinking skills than those in standard learning. Moreover, students' mathematics self-efficacy increased significantly following implementation of the model. The analysis also found a statistically significant, though modest, relationship between mathematical critical thinking skills and mathematics self-efficacy. These results indicate that combining structured cognitive instruction with digital learning environments can enhance students' mathematical critical thinking and mathematics self-efficacy, while recognising that broader contextual factors influence their mathematics development achievement.

Keywords: CMI model, google classroom-based CMI model, google classroom, mathematical critical thinking skills, mathematics self-efficacy.

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INTRODUCTION

Despite ongoing curriculum reforms, Indonesian students' mathematics performance remains a major concern. According to the 2022 PISA results, their average mathematics score remains low (OECD, 2023), while national data indicate that high school students' numeracy competencies remain moderate despite the formal integration of higher-order thinking skills (HOTS) into the curriculum (Kemdikbudristek, 2024). This discrepancy suggests that policy-level emphasis on HOTS has not yet translated into substantial improvements in students' mathematical competencies, which are closely linked to the development of a country's human resources (Setiana et al., 2021). Mathematical critical thinking plays a key role in students' learning outcomes, as it involves higher-level cognitive processes such as problem solving, analysis, synthesis, and evaluation (Arisoy & Aybek, 2021; Szabo et al., 2020). However, cognitive competence alone is insufficient. Students' self-efficacy significantly influences their engagement, persistence, and effective use of critical thinking strategies. Low self-efficacy may hinder students from fully applying their cognitive abilities, even in learning environments designed to promote HOTS. Therefore, the persistent gap between curricular goals and numeracy outcomes underscores the need to examine mathematical critical thinking and self-efficacy simultaneously to develop instructional approaches that support higher-order thinking and prepare students to meet the challenges of the Society 5.0 era.

Repetition of knowledge, linking to real-world issues, and engaging in meaningful dialogue to share ideas can foster critical thinking skills (Dolapcioglu & Doðanay, 2022). Critical thinking skills serve as essential capital for individuals to solve complex problems and adapt to dynamic work environments (Cruz et al., 2020). Creating a classroom environment that supports student achievement is a key strategy for developing critical thinking skills (Dolapcioglu & Doðanay, 2022). Presenting contextual problems in learning can foster the interpretation and development of analytical skills, which are core components of critical thinking (Sutama et al., 2022). Indicators of mathematical critical thinking skills consist of (1) Interpretation, which is understanding problems by accurately identifying and writing down given information and questions; (2) Analysis, which is identifying relationships between questions and answers to determine appropriate solutions; (3) Evaluation, which is applying solutions correctly and assessing their validity, and (4) Inference that means using alternative solutions to verify results and draw conclusions (Sutama et al., 2022).

Mathematics learning in the classroom often focuses solely on finding the correct solution, overlooking the development of a deep understanding of mathematics (Dolapcioglu & Doðanay, 2022). The use of digital media can help simplify and visualise materials, thereby enhancing students' understanding of abstract concepts (Seruni et al., 2020). Google Classroom, as a digital platform, can be used by students to access learning materials and help organize collaborative group activities to solve problems (Suanse & Yuenyong, 2021). Teachers can utilize the assignment, quiz, or exam features in Google Classroom to efficiently assess student learning outcomes. The application of the quiz feature on the learning management system (LMS) platform has been shown to improve student learning outcomes (Delima et al., 2022; Gamage et al., 2019; López-Tocón, 2021). Google Classroom is effective in enhancing student learning performance (Sari et al., 2022; Turmuzi et al., 2024). The integration of Google Classroom in mathematics learning has been shown to facilitate the implementation of a structured didactic cycle, thereby enhancing the quality of students' learning experiences (Núñez-Naranjo et al., 2025). Technology support as a learning tool can improve student motivation and learning outcomes (Oumelaid et al., 2023).

High school mathematics education is progressively integrating digital tools within instructional models that explicitly foster students' critical thinking skills. The use of technology-supported problem-based learning (PBL) is well documented to improve students' critical thinking skills (Suparman et al., 2022). However, despite its classroom-level benefits, large-scale improvements in mathematics performance, as reflected in Indonesia's PISA results, remain limited. This suggests that instructional effectiveness depends not only on the choice of learning model but also on how its pedagogical principles are structured and implemented, particularly in supporting students' cognitive processes during problem-solving. A key distinction among instructional approaches is the degree of cognitive scaffolding provided. While PBL's flexibility offers pedagogical advantages, it may pose challenges for students who require clearer guidance when engaging with complex mathematical tasks. In contrast, the Comprehensive Mathematics Instruction (CMI) model provides an explicitly sequenced pedagogical framework that aligns the presentation of problems with students' cognitive development through three successive phases: develop understanding, solidify understanding, and practice understanding (Delima et al., 2021, 2023). Prior studies have shown that the CMI model can be effectively integrated with digital tools to enhance students' mathematical, critical, and creative thinking skills (Delima et al., 2022; Delima & Elfandi, 2025). Building on this evidence, the present study hypothesizes that embedding the CMI instructional syntax into the Google Classroom quiz feature can enhance students' mathematical critical thinking by offering structured cognitive scaffolding while maintaining opportunities for exploration and reflection (see Figure 1).

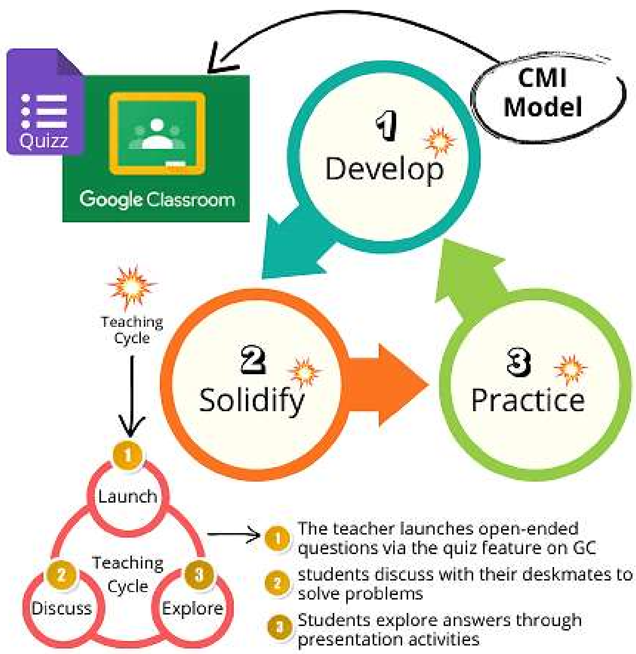


Figure 1. CMI model with google classroom

The CMI model is designed to promote cognitive engagement by systematically guiding students from exploring mathematical ideas and strategies toward understanding formal concepts, algorithms, and representations (Delima & Elfandi, 2025). Instruction emphasising cognitive activation and structured scaffolding has been shown to increase students' self-efficacy by enhancing their sense of competence and control during learning, particularly in digital or blended settings (Guo et al., 2023; H. Li et al., 2021). A growing body of research consistently identifies mathematics self-efficacy as a key factor influencing students' mathematics achievement and overall well-being, especially during adolescence when self-belief is still developing (Al Umairi, 2024; Ding et al., 2024; L. Li et al., 2020; Ortan et al., 2021; Ugwuanyi et al., 2020). Despite extensive research on mathematics self-efficacy, relatively few studies have examined its relationship with students' critical thinking skills in mathematics. From a social-cognitive perspective, self-efficacy develops through mastery experiences, vicarious experiences, verbal persuasion, and individuals' psychological states (Kontas & Ozcan, 2017; Ramdhani et al., 2017; Yuliyanto et al., 2021). These sources of self-efficacy are closely linked to learning activities that require students to engage in problem-solving, reflection, and mathematical reasoning, core processes within the CMI model. This theoretical alignment underscores the importance of examining how structured cognitive instruction, such as the CMI model implemented in digital environments, can simultaneously foster the development of mathematical critical thinking and mathematics self-efficacy.

This study expands the CMI model by integrating its cognitive sequencing and scaffolding into Google Classroom (GC). This integration enables automated management of students' learning progression in a blended learning environment. The key innovation here is to view GC not merely as a delivery tool but as a system-embedded pedagogical mechanism that translates the CMI syntax into digitally managed learning sequences. This digital implementation demonstrates how system-controlled pedagogy can enhance mathematical critical thinking and self-efficacy beyond traditional classroom settings. The study investigates whether the GC-based CMI model yields greater gains in students' mathematical critical thinking compared to standard instruction and examines changes in students' mathematics self-efficacy. This research examines the relationship between students' mathematical critical thinking and their mathematics self-efficacy, using the hypothesis model presented in Figure 2.

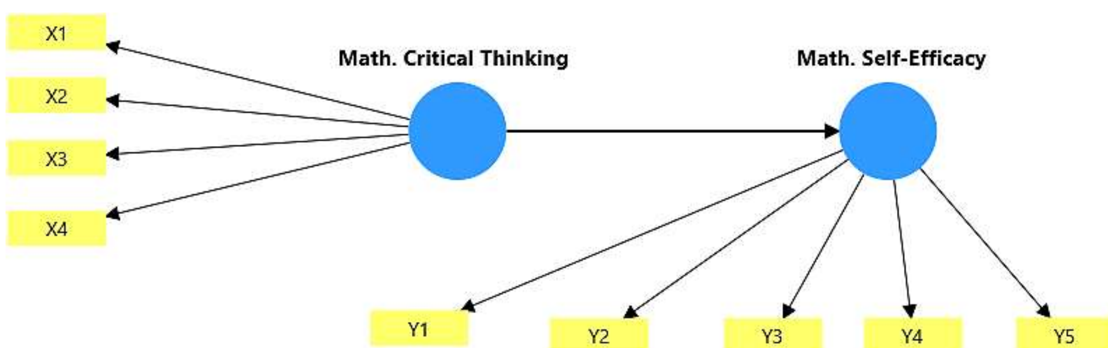


Figure 2. The hypothesis model for mathematical critical thinking and mathematics self-efficacy

■ METHOD

Participant

The study population consisted of all Grade 10 students at SMAN 1 Jalancagak, Subang Regency, West Java, Indonesia. The school holds an A accreditation, a status shared by approximately 53% of senior high schools in Subang Regency (Daftar-Sekolah, 2026), indicating that SMAN 1 Jalancagak is broadly representative of the regional secondary school context. For this reason, the school was selected to reflect typical instructional conditions in Subang Regency. Purposive sampling was used to select Classes X-9 and X-10 from the twelve Grade 10 classes based on quantitative and procedural factors. Specifically, school records from the previous semester, including students' mathematics exam scores, indicated that these two classes had similar average scores and distributions, mirroring the overall Grade 10 cohort. Additionally, both classes were taught by the same mathematics teacher and followed identical curricular content, thereby reducing instructional and contextual differences prior to the intervention. These criteria were intended to establish baseline equivalence between the experimental and control groups and to minimize threats to external validity. This equivalence was further confirmed by the absence of statistically significant differences in pretest scores between the two groups (see Table 1).

Table 1. Comparison test of students' critical thinking skills before the intervention

Class	N	Mean	Standard Deviation	Saphiro-Wilk			Comparison Test	
				Statistic	df	Sig.	Mann-Whitney U	Asymp. Sig. (2-tailed)
X-10	35	8.57	6.19	0.88	35	0.00	593.00	0.82
X-9	35	7.69	3.12	0.95	35	0.09		

Research Design and Procedures

This study employed a quasi-experimental design with a nonequivalent control group. Class X-10 was assigned as the experimental group and received instruction using a GC-based CMI model. In contrast, Class X-9 served as the control group and received the typical classroom instruction. As the school implements the *Merdeka* curriculum, classroom instruction typically follows a Problem-Based Learning (PBL) model. The intervention consisted of six instructional sessions. Before the intervention, both groups completed a pretest to assess their initial mathematical critical-thinking skills. The experimental group also completed a self-efficacy questionnaire to establish a baseline for their evaluation. After the intervention, both groups took a post-test to measure any changes in their mathematical critical thinking abilities. Additionally, the experimental group retook the self-efficacy questionnaire to assess any shifts in their confidence in mathematics.

The control group implemented the PBL model through five main stages. First, students were oriented to the problem by working in small groups and receiving student worksheets (LKPD) containing contextual problems related to data presentation. At this stage, students read the instructions, examine the problems, and gather initial information from textbooks and other relevant learning resources to understand them. Second, the learning process was organized by assigning roles and responsibilities within each group, with students studying supporting materials from textbooks and additional sources provided by the teacher. Third, during the guided inquiry stage, students discussed appropriate problem-solving strategies, collected the necessary data, and processed it to develop solutions to the data presentation problems. Fourth, students developed and presented their work by compiling a written report of their problem-solving results. One group presented its findings to the class, while other groups posed questions or provided feedback, which were then discussed collectively. Finally, students analysed and evaluated the problem-solving process by reflecting on solutions generated during class discussions and incorporating teacher feedback to strengthen their conceptual understanding.

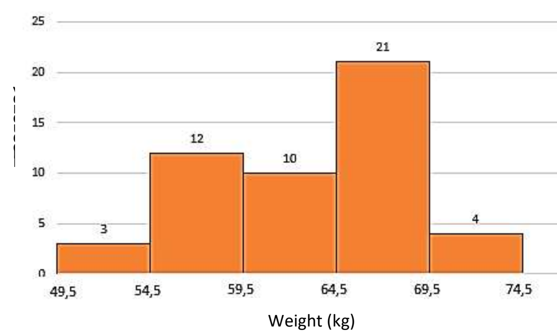
Instruments

The Indicators of mathematical critical thinking ability used in this instrument, consisted of four aspects (Sutama et al., 2022): (1) X1: Interpretation, students are required to be able to understand and express the intent or meaning of a problem; (2) X2: Analysis, students are required to be able to identify relationships between various statements, questions, concepts, descriptions and others; (3) X3: Evaluation, students can assess the credibility of a statement and the truth of a relationship between various statements, questions, concepts, descriptions and others; and (4) X4: Inference, students are required to be able to provide conclusions or provide reasons for the steps taken. The test used to measure mathematical critical thinking skills was a descriptive essay on Statistics (see Table 2), consisting of four items. Instrument testing was conducted with eleventh-grade high school students to ensure the validity and reliability of the research instrument before use with the main sample. These items had correlation coefficients (r) of 0.87, 0.89, 0.93, and 0.85, respectively, indicating very high validity. The Cronbach's alpha coefficient for the test was 0.91, indicating strong internal consistency (Izah et al., 2024). To ensure the objectivity and reliability of the mathematical critical thinking assessments, the scoring process involved two independent evaluators: the researcher (Rater 1) and a Grade XI mathematics teacher (Rater 2). The inter-rater reliability was statistically analysed using the Intraclass Correlation Coefficient (ICC) with a two-way mixed-effects model. The results yielded an ICC of 0.92, indicating Excellent reliability (Koo & Li, 2016). This high level of agreement confirms that the measurement of students' mathematical critical thinking skills was consistent and free from significant individual rater bias.

Indicators for measuring students' mathematics self-efficacy differ from the Yuliyanto self-efficacy instrument (Yuliyanto et al., 2021),

Table 2. Instrument test for students' critical thinking skills and scoring

Indicator	Problems	Scoring	
X1: Interpretation	In a playgroup, there are two groups, each consisting of five children. The first group has an average weight of 25 kg, while the second group has an average weight of 20 kg. One child from each group is exchanged, and after the exchange, the average weight of the two groups is equal. a. Interpret the given information by explaining what the average weight represents for each group before the exchange. b. Describe how exchanging one child from each group affects the total weight of each group. c. Represent the situation using mathematical expressions that show the condition for equal average weights after the exchange.	• Not writing what is known and what is asked.	0
		• Writing what is known and what is asked incorrectly.	1
		• Write only what is known exactly or only what is asked exactly.	2
		• Writing that is known from the question accurately but is incomplete.	3
		• Writing what is known and asked about from the question accurately and completely.	4
X2: Analysis	The following table presents the age distribution of employees in a company Age (years old) | Total 41 – 45 | 5 46 – 50 | 11 51 – 55 | x 56 – 60 | 4 61 – 65 | 1	• Do not create a mathematical model of the given problem.	0
		• Creating a mathematical model from the given problem, but not accurately.	1
		• Create a mathematical model from the given	2

<table>
<tr><td rowspan="3"></td><td rowspan="3">Given that the mode is 49.25, analyse which class interval must be the modal class and justify how this leads to the frequency of 51 – 55.</td><td>problem accurately without including an explanation.</td><td></td></tr>
<tr><td>• Creating a mathematical model from the given problem accurately, but there is an error in the explanation.</td><td>3</td></tr>
<tr><td>• Create a mathematical model from the given problem accurately and provide a complete and correct explanation.</td><td>4</td></tr>
<tr><td rowspan="5">X3: Evaluation</td><td rowspan="5">The data in the following frequency distribution table is the result of a test for entry into a company.
<table><tr><th>Applicants' scores</th><th>Number of applicants</th></tr><tr><td>51 – 60</td><td>9</td></tr><tr><td>61 – 70</td><td>16</td></tr><tr><td>71 – 80</td><td>25</td></tr><tr><td>81 – 90</td><td>16</td></tr><tr><td>91 – 100</td><td>14</td></tr><tr><td>Total</td><td>80</td></tr></table>
Is the cutoff score used to admit 60% of applicants appropriate? Justify your answer based on the distribution of scores.</td><td>• Not using a strategy to solve the problem.</td><td>0</td></tr>
<tr><td>• Using an incorrect and incomplete strategy in solving the problem.</td><td>1</td></tr>
<tr><td>• Using the right strategy to solve the problem, but incomplete, or using an incorrect strategy, but complete in solving the problem.</td><td>2</td></tr>
<tr><td>• Using the right strategy in solving problems, but making mistakes in calculations or explanations.</td><td>3</td></tr>
<tr><td>• Using the right strategy in solving problems, complete and correct in performing calculations or explanations.</td><td>4</td></tr>
<tr><td rowspan="5">X4: Inference</td><td rowspan="5">Examine the following diagram.


Based on the mean absolute deviation obtained from the histogram, what can be concluded about the variability of the data?</td><td>• Does not conclude the given problem.</td><td>0</td></tr>
<tr><td>• Drawing incorrect conclusions that are not in accordance with the context of the question.</td><td>1</td></tr>
<tr><td>• Making an incorrect conclusion, even though it is adjusted to the context of the question.</td><td>2</td></tr>
<tr><td>• Making an accurate conclusion, in accordance with the context, but not complete.</td><td>3</td></tr>
<tr><td>• Make an accurate conclusion, in accordance with the context of the question, and write it in full.</td><td>4</td></tr>
</table>

which refers to the following five dimensions: (1) Y1: Confidence in understanding the mathematical material. A person believes that they are capable of completing a certain task, where the individual themself determines what target must be completed; (2) Y2: Confidence in being able to motivate oneself to take the necessary actions to complete the task. A person can cultivate motivation in themself to choose and take the necessary actions to complete the task; (3) Y3: Confidence in being able to work hard, persistently, and diligently. There is a strong effort from a person to complete the assigned task using all the power they have; (4) Y4: Confidence in being able to survive facing obstacles and difficulties. A person can survive when facing difficulties and obstacles that arise and can recover from failure; (5) Y5: Confidence in being able to complete tasks that have a wide or specific range. A person believes that any task can be completed, whether broad or specific.

The student self-efficacy questionnaire used in this study consists of 9 statements (see Table 3), each presented as a Likert item with 4 response options: strongly agree, agree, disagree, and strongly disagree. The self-efficacy scale used in this study comprises both positive and negative items (reverse-coded). Specifically, items 3, 5, 7, 8, and 9 are negative statements designed to minimize response bias. To ensure data consistency, these items were processed using reverse scoring. While positive items were scored on a 4-point Likert scale (4, 3, 2, 1), negative items were scored in reverse (1, 2, 3, 4). This transformation ensures that a higher total score consistently represents a higher level of student self-efficacy across all items. This questionnaire has been tested on Grade XI students to assess its validity. The construct validity of the mathematics self-efficacy scale was assessed through Confirmatory Factor Analysis (CFA). After reverse-scoring the negative items (Y3, Y5, Y7, Y8, and Y9), the measurement model demonstrated an acceptable fit (CFI = 0.928, RMSEA = 0.068). The standardized loading factors are 0.69, 0.74, 0.63, 0.49, 0.77, 0.54, 0.40, 0.65, and 0.64, respectively. Furthermore, the Construct Reliability (CR) was 0.86, exceeding the recommended threshold of 0.70, indicating high internal consistency (Hair et al., 2017).

Table 3. Mathematics self-efficacy instrument

Indicators	Statements
Y1: Confident of being able to complete a particular task	1. I can understand mathematical material.
	2. I am confident that I can complete the assignments given by my teacher.
	3. I give up easily when faced with difficult problems.
Y2: Confident that you can motivate yourself to take the necessary actions to complete the task	4. I can cultivate my own motivation to choose and take the necessary actions to complete assignments.
	5. I often feel lazy and unwilling to put in the effort to study.
Y3: Believe that you are capable of working hard, persistently, and diligently	6. I always try to find ways to complete tasks even when they are difficult.
	7. I easily lose my motivation to study when I experience failure.
Y4: Confident that oneself is capable of enduring obstacles and difficulties	8. I tend to give up if I don't succeed immediately at a task.

Y5: Confident in completing tasks that have a broad or specific range	9. I struggle with tasks that differ from my usual approach.

Data Analysis

This research proposes three research hypotheses, including:

H_1 : The improvement in students' mathematical critical thinking skills who received the CMI model based on Google Classroom (GC) is better than that of those who received the PBL model.

H_2 : There is a significant change in students' self-efficacy before and after learning using the CMI model based on GC.

H_3 : There is a significant influence of students' mathematical critical thinking ability on self-efficacy.

Hypothesis 1 (H_1) is tested using the Mann-Whitney test with normalized gain (N-gain) scores of the experimental and control classes. The Mann-Whitney test was used because the N-gain score data of the experimental class were not normally distributed. Hypothesis 2 (H_2) tests paired ordinal data; therefore, the Wilcoxon test is used. Hypothesis 3 (H3) was tested using PLS-SEM, as the data do not meet the assumptions of linear regression and are not normally distributed. Additionally, PLS-SEM can be used for analysing small sample sizes (Jhantasana, 2023; Kock & Hadaya, 2018).

RESULT AND DISCUSSION

Mathematical Critical Thinking Skills and The CMI Model with GC

This section discusses hypothesis 1 (H1). Descriptive statistics of the N-gain score data for students' mathematical critical thinking (MCT) abilities are presented in Table 4.

Table 4. Descriptive statistics of the N-gain score of students' critical thinking skills

Class	Mean	Standard Deviation	Criteria
Experiment (MCT)	0.77	0.18	High level
1. Interpretation	0.84	0.17	High level
2. Analysis	0.66	0.75	Moderate level
3. Evaluation	0.84	0.17	High level
4. Inference	0.66	0.29	Moderate level
Control (MCT)	0.36	0.10	Moderate level
1. Interpretation	0.43	0.11	Moderate level
2. Analysis	0.32	0.08	Moderate level
3. Evaluation	0.44	0.19	Moderate level
4. Inference	0.25	0.18	Low level

The normality test of the N-gain scores of both classes showed that the N-gain scores of the experimental class were not normally distributed (see Figure 3), so a Mann-Whitney test was conducted with a significance level of 0.05 to test the following hypothesis:

H_0 : There is no difference in the increase in mathematical critical thinking skills between students in the experimental class and the control class.

H_1 : There is a difference in the increase in mathematical critical thinking skills between students in the experimental class and the control class.

The asymptotic significance from the Mann-Whitney test is 0.000. This indicates that H_0 is rejected. Table 1 shows that the average N-gain score of the experimental class is greater than that of the control class, and the N-gain criteria of the experimental class are at a high level, while the control class is at a moderate level. Thus, this study demonstrates that the increase in students' mathematical critical thinking skills under the GC-based CMI model is superior to that under the PBL approach.

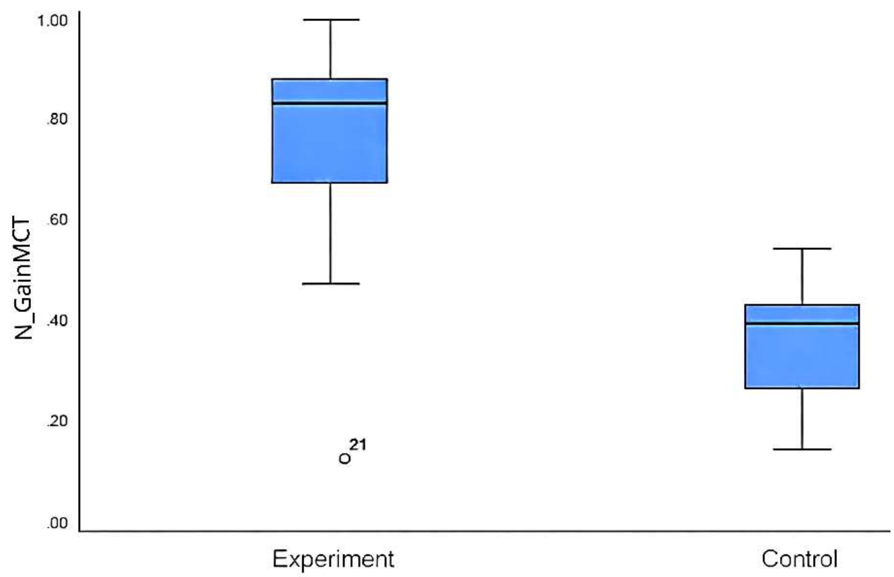


Figure 3. Boxplot of N-gain data

In the first meeting, students spent considerable time completing the GC student worksheet because they had not yet adapted to the CMI model used there. Students were surprised because, during this learning process, they had to complete three worksheets simultaneously in a single session. Students were still hesitant to ask questions about parts of the worksheet they did not understand. To address this, the teacher circled the room, checked each student, and guided them as they worked on the worksheet. From the third to the sixth meeting, the learning process became increasingly smooth and aligned with the stages of the CMI-based GC learning model. Students had become accustomed to the learning process, marked by increasingly active responses, smoother discussions, and improved completion of worksheets in accordance with instructions. As a result, students became more confident and less hesitant to present their work to the class.

The GC-based CMI model provides explicit pedagogical prescriptions that guide students in activating their cognitive processes. Learning strategies that activate cognitive processes enhance students' academic achievement in mathematics (H. Li et al., 2021; Zuo et al., 2024). The GC-based CMI model offers students the opportunity to learn in adaptive conditions. Each student's learning achievement will vary because the CMI model offers a differentiated learning environment (Delima et al., 2022). Learning activities in GC foster the development of higher-order thinking skills, particularly analysis and evaluation (Lau et al., 2020). GC-based learning enables teachers to serve as facilitators and scaffolders, helping students solve complex problems (Ramadhani et al., 2020).

At the development stage, the teacher's role is to facilitate students' generation of problem-solving ideas. The problem exploration process outlined in the develop stage is the first step for students to develop problem-solving strategies appropriate to the mathematical concepts being studied. The questions posed at the *Develop* stage are intentionally designed as open-ended mathematical tasks that activate students' interpretation, analysis, and evaluation processes (see Figure 4(a)). Rather than focusing on procedural computation, these tasks require students to extract meaning from raw data, analyse patterns, and evaluate appropriate mathematical representations. Such cognitive demands align with the operational definition of mathematical critical thinking adopted in this study. Previous studies indicate that open-ended tasks can enhance creative thinking (Kwon et al., 2006; Suryawan & Sariyasa, 2018). In the GC-based CMI model, these tasks are delivered through GC quizzes. Students can only move on to the solidify stage after completing the develop stage. If they haven't accomplished this, they need to revisit and complete the tasks until they can demonstrate mastery.

The difference between the CMI model and PBL lies in the types of problems presented and the way they are presented. The problems presented in the CMI model are open-ended, whereas PBL does not specify the types of problems that can be given to students. At the solidify stage, the student is given problems that can stimulate their understanding of concepts and help them transform these concepts into mathematical properties. The types of problems in this stage are presented as multiple-choice and pairing questions, as shown in GC (see Figure 4(b)). Students discuss each step in solving the problem with a deskmate, then present their work to others. This process will help students identify mathematical concepts in every problem they encounter. The teacher will decide who passes this stage based on their answers and activities during the presentation session. Discussing the problem-solving process with a desk mate is an example of collaborative learning. Collaborative learning has been proven to cultivate mathematical critical thinking (Sutama et al., 2022).

The final step of the CMI model is the practice stage. This stage presents students with problems that help them discover certain mathematical properties. The student is stimulated to apply the mathematical concepts they have solidified to solve the problems given in this stage. A student who passes this stage may proceed to study additional material, beginning at the develop stage again. However, if they have not yet completed their exploration of the properties of the given problems, they must remain at this stage until they have finished. The problems presented in this stage are arranged as multiple-choice and true-or-false questions and appear in the GC (see Figure 4(c)). Students must present their reasoning for the answer they choose. This process cultivates confidence in reasoning, one of the dispositions of critical thinking, and, in turn, affects students' critical thinking (Facione, 2011; Syamsulrizal et al., 2025). Therefore, the GC-based CMI model is effective in enhancing mathematical critical thinking.

Although both the Problem-Based Learning (PBL) and the GC-based CMI models emphasize student-centred learning, they differ fundamentally in their structures and cognitive control. In the control class implementing PBL, students engaged with open-ended problems and were encouraged to collaboratively explore solutions with flexible teacher guidance. While this promotes inquiry and discussion, it also requires students to self-regulate their learning, which may disadvantage those who

The Develop Stage Problems

The math scores for 20 students are as follows:

73, 75, 75, 73, 78, 78, 80, 78, 80, 78, 83, 81, 82, 83, 81, 87, 85, 85, 91, 90.

1. What can you conclude from the data above?
2. How would you present the data above to make it more informative and easier to understand?

(a)

The Solidify Stage Problems

1. The height data for 23 players on the Indonesian U-23 National Team is as follows:
   180, 168, 181, 177, 182, 186, 178, 170, 180, 187, 185, 172, 185, 171, 176, 165, 178, 172, 169, 180, 180, 185, 171.
   Which of the following tables correctly presents this data?

A

Height (cm)	Frequency
165-168	2
169-172	6
173-176	1
177-180	7
181-184	2
185-188	5
Total	23

B

Height (cm)	Frequency
165-169	3
170-174	5
175-179	4
180-184	5
185-190	6
Total	23

C

Height (cm)	Frequency
165-168	3
169-172	5
173-176	7
177-180	5
181-184	3
Total	23

D

Height (cm)	Frequency
165-168	2
169-172	6
173-176	1
177-180	5
181-184	3
185-188	6
Total	23

2. Based on the answer to number 1. Match the following questions with the correct answers.

If the midpoint (xi) is half of the Upper Limit + Lower Limit then the midpoint of the 4th class interval is…	◯	◯ 176.5
If Lower Edge = Lower Limit - 0.5, then the lower edge of the 4th class interval is...	◯	◯ 180.5
If Upper Edge = Upper Limit - 0.5, then the upper edge of the 4th class interval is...	◯	◯ 178.5

(b)

The Practice Stage Problems

For problems number 1 and 2, look at the following frequency distribution table

Score	Number of Students
50 – 59	4
60 – 69	7
70 – 79	11
80 – 89	9
90 – 100	4
Total	35

1. The lower limit of the first class is 50, and the upper limit is 59 (True/False). Explain your reasoning!
2. From question number 1, the midpoint for the second class interval is 64.5 (True/False). Explain your reasoning!
3. In a histogram, the bars are always separate because they represent categorical data. (True/False). Explain your reasoning!
4. If an ogive rises more sharply, it means there is more data in that interval. (True/False). Explain your reasoning!
5. An upward ogive is used to determine the number of data points less than or equal to a certain value, while a downward ogive is used to determine the number of data points greater than or equal to a certain value. (True/False). Explain your reasoning!

(c)

Figure 4. The problems in the CMI model with google classroom

lack advanced problem-solving or metacognitive skills. Conversely, the GC-based CMI model provides a clearer, step-by-step instructional framework that guides students through distinct cognitive stages: understanding, consolidating, and practising it. Access to each stage is governed by Google Classroom quizzes that students must pass to advance to the next stage. This structured progression embeds cognitive scaffolding directly into the learning design, reducing extraneous cognitive load and supporting students as they gradually develop mathematical reasoning. As a result, students encounter complex, open-ended problems and are supported in analysing, interpreting, and evaluating them in a structured and adaptable way. These differences in teaching explain why students in the GC-based CMI class showed greater improvement in mathematical critical thinking skills than those in the PBL class. While PBL largely depends on students' ability to independently handle problem complexity, the GC-based CMI model adjusts the difficulty level to match students' cognitive readiness and provides instant feedback via digital assessment. This method, which combines structured guidance with adaptive learning environments, appears more effective at maintaining engagement, encouraging deeper reasoning, and enhancing confidence in mathematics problem-solving.

Mathematics Self-Efficacy and the CMI Model with GC

This section answers hypothesis 2 (H_2). Comparison of students' mathematics self-efficacy scores before and after learning using the GC-based CMI model is presented in Figure 5. If we pay closer attention to the Figure, we can see that students' mathematics self-efficacy scores differ before and after learning using the GC-based CMI. Students' mathematics self-efficacy scores are categorized into an ordinal scale. Therefore, to test Hypothesis 2, nonparametric statistics are used.

The mathematics self-efficacy questionnaire data were analysed using non-parametric statistics. The Wilcoxon test, with a significance level of 0.05 as presented in Table 5, was used to test the following hypotheses:

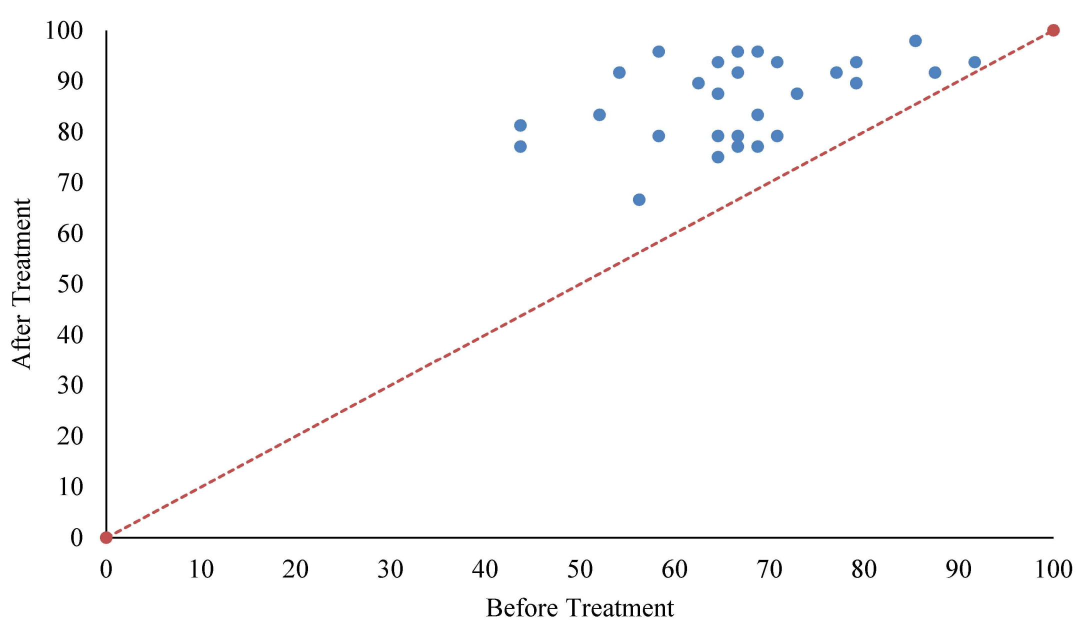


Figure 5. Students' mathematics self-efficacy before and after treatment

H_0 : There was no significant difference in self-efficacy between before and after treatment with the GC-based CMI model.

H_1 : There is a significant difference in self-efficacy between before and after treatment with the GC-based CMI model.

Table 5. The wilcoxon test of the mathematics self-efficacy questionnaire scores

		N	Mean Rank	Sum of Ranks	Asymptotic sig.
Before treatment-After treatment	Negative Ranks	0[a]	0	0	0.000
	Positive Ranks	35[b]	18	630	
	Ties	0[c]			
	Total	35			

a. Before treatment < After treatment
b. Before treatment > After treatment
c. Before treatment = After treatment

The Wilcoxon signed-rank test results show a statistically significant increase in students' mathematics self-efficacy after implementing the GC–based CMI model. The absence of negative ranks and ties suggests that all students in the experimental group experienced an increase in mathematics self-efficacy after the intervention, indicating a consistent positive shift across participants. This finding indicates that the GC-based CMI model enhances mathematics self-efficacy among individuals and fosters consistent improvement across students with varying baseline confidence levels. The notable improvement following treatment demonstrates that the GC-based CMI model's structured cognitive sequencing and embedded scaffolding effectively increase students' confidence in engaging with mathematical tasks. Collectively, these results reinforce the role of digitally regulated instructional models in strengthening affective learning outcomes, particularly students' beliefs about their mathematical capabilities.

The CMI model has a teaching cycle that provides students with the opportunity to present their work results at the exploration stage (Delima et al., 2022). At this stage, the teacher assesses and determines whether the student is ready to proceed to the next step. This process builds students' self-efficacy, enabling them to become more confident in completing their tasks. The Google Classroom-based CMI model is a structured form of flipped learning. It allows students to study learning materials independently outside of class, while in-class sessions focus on discussion and problem-solving. Flipped learning in mathematics education can improve students' self-efficacy (Algarni & Lortie-Forgues, 2023; Jamaluddin et al., 2023; Yorganci, 2020). The discussion process within the GC-based CMI model helps students build confidence in completing teacher-assigned mathematics assignments and provides them with the opportunity to understand problems independently. The process of determining the depth of students' understanding can be observed in problem-solving discussions. Peer discussion can improve mathematics achievement (L. Li et al., 2020).

The positive change in students' self-efficacy observed in this study can be interpreted through the lens of Bandura's self-efficacy framework rather than as direct evidence of specific psychological mechanisms (Kontas & Ozcan, 2017). The GC-based CMI model requires students to engage with tasks sequentially and complete each stage before progressing, a structure that provides repeated opportunities for successful task completion. According to self-efficacy theory, such experiences are associated with mastery experiences, which are known to contribute to the development of self-efficacy. However, the present study did not directly measure mastery experiences; thus, this interpretation is inferred from the alignment between the CMI syntax instructional design and established theoretical constructs.

Similarly, the exploration stage, in which students present and justify their problem-solving processes, may contribute to students' confidence by engaging affective and cognitive processes related to self-regulation and performance validation. Teacher feedback and encouragement during GC–based CMI learning can also be interpreted as forms of verbal persuasion, which previous studies have identified as influential sources of self-efficacy development (Yuliyanto et al., 2021; Yuliyanto & Turmudi, 2020). Additionally, peer discussion during collaborative activities can serve as vicarious experiences, enabling students to observe and compare strategies with their peers. Although these mechanisms were not directly observed or measured in this study, the significant improvement in self-efficacy scores suggests that the instructional features of the GC-based CMI model align with theoretical conditions that support self-efficacy development. Therefore, the findings provide empirical support for the effectiveness of the GC-based CMI model in enhancing students' self-efficacy. Future studies are needed to examine these psychological mechanisms more directly through observational or qualitative data.

Students' Mathematical Critical Thinking Ability and Mathematics Self-Efficacy

Hypothesis 3 testing was conducted using PLS-SEM because the latent variables of mathematical critical thinking ability and mathematics self-efficacy are unobservable (Hair et al., 2017). Mathematical critical thinking ability falls under the cognitive aspect, with four indicators, whereas self-efficacy falls under the affective aspect, with five indicators. Convergent validity test using outer loading, composite reliability (CR), and average variance extracted (AVE) (Jhantasana, 2023), while the discriminant validity test uses the Heterotrait–Monotrait Ratio method (HTMT). Table 6 demonstrates that all indicators contributing to the latent variables possess both convergent and discriminant validity, meeting the requirements for use as a measurement model.

The evaluation of the structural model between mathematical critical thinking ability and mathematics self-efficacy presented in Figure 6.

Table 6. The evaluation of the measurement model of the latent variables

	Latent Variable	Indicator	Outer Loading		CR		AVE	
			O	**p-value**	**O**	**p-value**	**O**	**p-value**
X	Mathematical Critical Thinking	X1	0.876	0.000	0.945	0.000	0.811	0.000
		X2	0.908	0.000				
		X3	0.885	0.000				
		X4	0.932	0.000				
Y	Mathematics Self-Efficacy	Y1	0.812	0.000	0.812	0.000	0.469	0.000
		Y2	0.684	0.004				
		Y3	0.605	0.017				
		Y4	0.537	0.015				
		Y5	0.751	0.001				
X ↔Y		Heterotrait–Monotrait Ratio (HTMT) = 0.256						

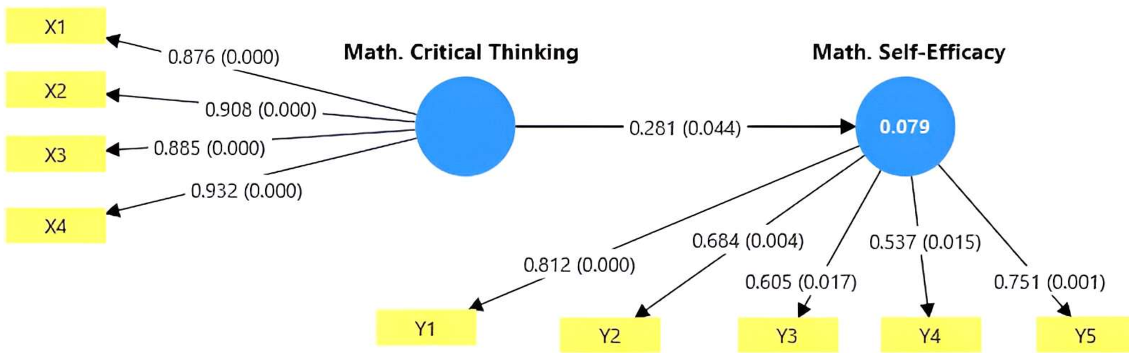


Figure 6. The structural model of latent variables

Hypothesis H_3 testing, including: (a) collinearity testing (VIF-inner model), (b) significance testing of the structural model relationship (path coefficient), (c) effect size measurement (f^2), (d) measurement of the coefficient of determination (R^2), dan (e) predictive relevance measurement (Q^2) (Hair et al., 2017).

Table 7. Evaluation of the structural model

The latent variable	VIF	Path coefficient		f^2	R^2	Q^2
		O	p-value			
Math. Critical Thinking → Math Self-Efficacy	1.000	0.281	0.044	0.086	0.079	0.014

Table 7 shows that although the path from mathematical critical thinking (MCT) to mathematics self-efficacy is statistically significant, the very low R^2 value (0.079), weak effect size ($f^2 = 0.086$), and limited predictive relevance ($Q^2 < 0.015$) clearly indicate that MCT is not a substantive predictor of students' self-efficacy in this study 015 (Al Umairi, 2024; Hair et al., 2017). This result constitutes a theoretically important anomaly. Prevailing theoretical frameworks and prior empirical studies generally posit that successful engagement in cognitively demanding mathematical tasks should strengthen students' self-efficacy through mastery experiences (Al Umairi, 2024). However, the present findings contradict this expectation, suggesting that improvements in mathematical critical thinking do not necessarily translate into meaningful gains in self-efficacy.

This contradiction can be explained by the distinct developmental mechanisms underlying the two constructs. Mathematical critical thinking reflects higher-order cognitive processes, including analysis, interpretation, and evaluation. In contrast, mathematics self-efficacy is an affective construct shaped by students' confidence, emotional regulation, and perceived control over learning tasks. In the context of the GC-based CMI intervention, self-efficacy gains appear to have been driven more directly by instructional features, such as structured task sequencing, controlled progression between learning stages, repeated opportunities for successful task completion, and immediate feedback via Google Classroom, rather than by students' level of critical thinking itself. As a result, self-efficacy improved through pedagogical and contextual supports embedded in the learning environment, independently of the cognitive gains achieved.

Thus, the low R^2 value should be interpreted cautiously and does not necessarily indicate a methodological weakness. Rather, this study suggests that mathematical critical thinking is not a dominant predictor of students' mathematics self-efficacy. This finding invites a more nuanced interpretation of existing theoretical models that propose a close link between cognitive skill development and self-efficacy, suggesting that these relationships may be context-dependent rather than universal. Consistent with prior studies, self-efficacy appears to emerge from a combination of cognitive performance, emotional regulation, and contextual learning experiences, rather than from cognitive achievement alone (Olivier et al., 2019; Wang et al., 2025). Therefore, while improvements in mathematical critical thinking may contribute to the development of self-efficacy, the present results suggest that instructional interventions should also incorporate explicit motivational and affective supports to meaningfully enhance students' mathematics self-efficacy.

■ CONCLUSION

This study demonstrates that the improvement in students' mathematical critical thinking skills achieved through the Google Classroom (GC)-based Comprehensive Mathematics Instruction (CMI) model exceeds that achieved through the PBL model. The GC-based CMI model employs a structured syntax that regulates the presentation of problems according to increasing levels of cognitive demand, in which students must complete the develop stage before progressing to the solidify and practice stages. This sequential learning access is automated through the quiz feature in GC, ensuring mastery-based progression. In addition, the findings indicate that the GC-based CMI model enhances students' mathematics self-efficacy, and students who demonstrate higher levels of mathematical critical thinking also tend to report higher self-efficacy.

Despite these promising findings, it is important to recognize some limitations. First, the study employed purposive sampling, selecting participants from a single senior high school, which may limit the generalizability of the results to a broader student population. The use of non-probability sampling restricts the extent to which the findings can be extrapolated beyond the study context. Second, the study examined improvements in critical thinking skills and self-efficacy over a relatively short intervention period, focusing exclusively on statistics content. Therefore, future research should employ probability-based sampling across multiple schools, investigate a wider range of mathematical topics, and examine the long-term retention of students' critical thinking skills and the development of self-efficacy over time. Furthermore, the GC-based CMI model's syntax could be extended into a digital adaptive assessment framework to support differentiated learning across more diverse educational contexts.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the author(s) used ChatGPT to assist with language refinement and proofreading. The author(s) have reviewed and edited the content generated by this tool and assume full responsibility for the content of the published article.

■ REFERENCES

Al Umairi, K. S. (2024). Role of mathematics motivation in the relationship between mathematics self-efficacy and achievement. *Journal of Pedagogical Research*, *8*(4), 125–146. https://doi.org/10.33902/JPR.202428560

Algarni, B., & Lortie-Forgues, H. (2023). An evaluation of the impact of flipped-classroom teaching on mathematics proficiency and self-efficacy in Saudi Arabia. *British Journal of Educational Technology*, *54*(1), 414–435. https://doi.org/10.1111/bjet.13250

Arisoy, B., & Aybek, B. (2021). The effects of subject-based critical thinking education in mathematics on students' critical thinking skills and virtues. *Eurasian Journal of Educational Research*, *2021*(92), 99–120. https://doi.org/10.14689/ejer.2021.92.6

Cruz, G., Payan-Carreira, R., Dominguez, C., Silva, H., & Morais, F. (2020). What critical thinking skills and dispositions do new graduates need for professional life? Views from Portuguese employers in different fields. *Higher Education Research and Development*, 1–17. https://doi.org/10.1080/07294360.2020.1785401

Daftar-Sekolah, N. (2026). *Daftar SMA negeri dan swasta di jawa barat tahun 2026*.

Delima, N., & Elfandi, P. (2025). Improving mathematical thinking and digital literacy skills through the comprehensive mathematics instruction (CMI) model assisted by geogebra. *AIP Conference Proceedings*, *3142*(1), 020056–1–020056–020058. https://doi.org/10.1063/5.0262298

Delima, N., Elfandi, P., Ramadhani, D. D., Nurhayati, W. S., Budiman, G. K. P., & Fatrizian, D. A. (2023). *Meningkatkan kemampuan berpikir kritis dan kreatif matematis serta literasi digital siswa melalui model blended-comprehensive mathematics instruction berbantuan geogebra* [Improving students' critical and creative mathematical thinking skills and digital literacy through a blended-comprehensive mathematics instruction model assisted by geogebra]. *Biormatika/ : Jurnal Ilmiah Fakultas Keguruan Dan Ilmu Pendidikan*, *9*(1), 37–44. https://doi.org/10.35569/biormatika.v9i1.1432

Delima, N., Jaja, J., & Kusuma, D. A. (2022). Digital teaching materials using comprehensive mathematics instruction model for interactive mathematics learning. *Jurnal Pendidikan MIPA*, *23*(4), 1777–1789. https://doi.org/10.23960/jpmipa/v23i4.pp1777-1789

Delima, N., Kusumah, Y. S., & Fatimah, S. (2021). *Capaian kemampuan mathematical thinking siswa melalui model comprehensive mathematics instructions* [Students' mathematical thinking ability achievement through the comprehensive mathematics instructions model]. *Jurnal Elemen*, *7*(1), 146–163. https://doi.org/10.29408/jel.v7i1.2793

Ding, Y., Klapp, A., & Yang Hansen, K. (2024). The importance of mathematics self-concept and self-efficacy for mathematics achievement: A comparison between public and independent schools in Sweden. *Educational Psychology*, *44*(8), 872–892. https://doi.org/10.1080/01443410.2024.2410217

Dolapcioglu, S., & Doðanay, A. (2022). Development of critical thinking in mathematics classes via authentic learning: an action research. *International Journal of Mathematical Education in Science and Technology*, *53*(6), 1363–1386. https://doi.org/10.1080/0020739X.2020.1819573

Facione, P. A. (2011). Critical thinking/ : what it is and why it counts. *Insight Assessment*, *ISBN 13: 978-1-891557-07-1.*, 1–28. https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and-Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF

Gamage, S. H. P. W., Ayres, J. R., Behrend, M. B., & Smith, E. J. (2019). Optimising Moodle quizzes for online assessments. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-019-0181-4

Guo, Y., Wang, Y., & Ortega-Martín, J. L. (2023). The impact of blended learning-based scaffolding techniques on learners' self-efficacy and willingness to communicate. *Porta Linguarum*, *2023*(40), 253–273. https://doi.org/10.30827/portalin.vi40.27061

Hair, J. F., Hult, G. T., Ringle, C., & Sarstedt, M. (2017). A primer on partial least squares structural equation modeling (PLS-SEM). In *Sage* (Second). SAGE Publications Inc.

Izah, S. C., Sylva, L., & Hait, M. (2024). Cronbach's alpha: a cornerstone in ensuring reliability and validity in environmental health assessment. *ES Energy and Environment*, *23*, 1–14. https://doi.org/10.30919/esee1057

Jamaluddin, M., Mustaji, M., Bachri, B. S., & Sutarto, A. P. (2023). The role of gender and self-efficacy on the relationship between flipped and flex blended learning and mathematics abilities. *International Journal of Information and Education Technology*, *13*(5), 873–881. https://doi.org/10.18178/ijiet.2023.13.5.1882

Jhantasana, C. (2023). Should a rule of thumb be used to calculate PLS-SEM sample size. *Asia Social Issues*, *16*(5), e254658. https://doi.org/10.48048/asi.2023.254658

Kemdikbudristek. (2024). Indonesia's 2024 education report card (rapor pendidikan indonesia tahun 2024). in *merdeka belajar*. https://raporpendidikan.kemdikbud.go.id/login

Kock, N., & Hadaya, P. (2018). Minimum sample size estimation in PLS-SEM: The inverse square root and gamma-exponential methods. *Information Systems Journal*, *28*(1), 227–261. https://doi.org/10.1111/isj.12131

Kontas, H., & Ozcan, B. (2017). Adapting sources of middle school mathematics self-efficacy scale to turkish culture. *International Journal of Evaluation and Research in Education (IJERE)*, *6*(4), 288. https://doi.org/10.11591/ijere.v6i4.10771

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Kwon, O. N., Park, J. S., & Park, J. H. (2006). Cultivating divergent thinking in mathematics through an open-ended approach. *Asia Pacific Education Review*, *7*(1), 51–61. https://doi.org/10.1007/BF03036784

Lau, J. C. L., Moses, P., Cheah, P. K., & Francis, K. (2020). A review of past studies: Connecting Google Classroom learning activities with digital & information literacy linked to Bloom's taxonomy of educational objectives. In *ICCE 2020 - 28th International Conference on Computers in Education, Proceedings* (Vol. 2, pp. 451–460). Asia-Pacific Society for Computers in Education (APSCE). https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85099569623&origin=inward

Li, H., Liu, J., Zhang, D., & Liu, H. (2021). Examining the relationships between cognitive activation, self-efficacy, socioeconomic status, and achievement in mathematics: A multi-level analysis. *British Journal of Educational Psychology*, *91*(1), 101–126. https://doi.org/10.1111/bjep.12351

Li, L., Peng, Z., Lu, L., Liao, H., & Li, H. (2020). Peer relationships, self-efficacy, academic motivation, and mathematics achievement in Zhuang adolescents: A moderated mediation model. *Children and Youth Services Review*, *118*. https://doi.org/10.1016/j.childyouth.2020.105358

López-Tocón, I. (2021). Moodle quizzes as a continuous assessment in higher education: An exploratory approach in physical chemistry. *Education Sciences*, *11*(9), 1–12. https://doi.org/10.3390/educsci11090500

Núñez-Naranjo, A., Aimacaña-Aimacaña, R., Navas-Franco, L., Reyes, J., Escobar-Bermúdes, D., & Moposita, M. (2025). Strengthening the Didactic Cycle of Mathematics Through Google Classroom. *Lecture Notes in Networks and Systems*, *858 LNNS*, 527–535. https://doi.org/10.1007/978-3-031-74751-9_50

OECD. (2023). PISA 2022 Result: The state of learning and equity in education. In *PISA 2022: Vol. I*. OECD Publishing. https://doi.org/10.31244/9783830998488

Olivier, E., Archambault, I., De Clercq, M., & Galand, B. (2019). Student self-efficacy, classroom engagement, and academic achievement: comparing three theoretical frameworks. *Journal of Youth and Adolescence*, *48*(2), 326–340. https://doi.org/10.1007/s10964-018-0952-0

Ortan, F., Simut, C., & Simut, R. (2021). Self-efficacy, job satisfaction, and teacher well-being in the K-12 educational system. *International Journal of Environmental Research and Public Health*, *18*(23). https://doi.org/10.3390/ijerph182312763

Oumelaid, N., El-Mrabte, F., El-Boukari, B., & Elghordaf, J. (2023). Enhancing learners' performance: exploring the combined impact of web-based mathematics self-learning and homework resources on classroom test scores. *International Journal of Information and Education Technology*, *13*(12), 1899–1906. https://doi.org/10.18178/ijiet.2023.13.12.2003

Ramadhani, R., Bina, N. S., Sihotang, S. F., Narpila, S. D., & Mazaly, M. R. (2020). Students' critical mathematical thinking abilities through flip-problem based learning model based on LMS Google Classroom. In *Journal of Physics: Conference Series* (Vol. 1657, Issue 1). IKIP Siliwangi. https://doi.org/10.1088/1742-6596/1657/1/012025

Ramdhani, M. R., Usodo, B., & Subanti, S. (2017). Student's mathematical understanding ability based on self-efficacy. *Journal of Physics: Conference Series*, *909*(012065). https://doi.org/doi/:10.1088/1742-6596/909/1/012065

Sari, A. K., Sugiman, & Retnowati, E. (2022). Google Classroom using worked example strategy: Its effectiveness on learning mathematics. In *AIP Conference Proceedings* (Vol. 2575). https://doi.org/10.1063/5.0107863

Seruni, R., Munawaroh, S., Kurniadewi, F., & Nurjayadi, M. (2020). Implementation of e-module flip PDF professional to improve students' critical thinking skills through problem-based learning. *International Conference on Mathematics and Science Education 2019 (ICMScE, 2019) Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042085

Setiana, D. S., Purwoko, R. Y., & Sugiman. (2021). The application of mathematics learning model to stimulate mathematical critical thinking skills of senior high school students. *European Journal of Educational Research*, *10*(1), 509–523. https://doi.org/10.12973/EU-JER.10.1.509

Suanse, K., & Yuenyong, C. (2021). Development of the analytic geometry flipped classroom teaching model through Google Classroom. In *Journal of Physics: Conference Series* (Vol. 1835, Issue 1). https://doi.org/10.1088/1742-6596/1835/1/012077

Suparman, S., Juandi, D., Martadiputra, B. A. P., Badawi, A., Susanti, N., & Yunita. (2022). Cultivating secondary school students' mathematical critical thinking skills using technology-assisted problem-based learning: a meta-analysis. In *AIP Conference Proceedings* (Vol. 2468). https://doi.org/10.1063/5.0102422

Suryawan, I. P. P., & Sariyasa. (2018). Integrating ethnomathematics into open-ended problem-based teaching materials. *Journal of Physics: Conference Series*, *1040*(1). https://doi.org/10.1088/1742-6596/1040/1/012033

Sutama, S., Fuadi, D., Narimo, S., Hafida, S. H. N., Novitasari, M., Anif, S., Prayitno, H. J., Sunanih, S., & Adnan, M. (2022). Collaborative mathematics learning management: Critical thinking skills in problem solving. *International Journal of Evaluation and Research in Education*, *11*(3), 1015–1027. https://doi.org/10.11591/ijere.v11i3.22193

Syamsulrizal, S., Khabibah, S., Lukito, A., & Madzkiyah, A. F. (2025). Students' critical thinking dispositions in view of cognitive styles: exhibiting confidence in reasoning and inquisitive. *Perspektivy Nauki i Obrazovania*, *73*(1), 583–594. https://doi.org/10.32744/pse.2025.1.37

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability (Switzerland)*, *12*(23), 1–28. https://doi.org/10.3390/su122310113

Turmuzi, M., Suharta, G. P., Astawa, W. P., & Suparta, N. (2024). Misconceptions of mathematics in higher education universities when learning with google classroom based on learning styles and gender differences. *Journal of Technology and Science Education*, *14*(1), 200–223.

Ugwuanyi, C. S., Okeke, C. I. O., & Asomugha, C. G. (2020). Prediction of learners' mathematics performance by their emotional intelligence, self-esteem, and self-efficacy. *Cypriot Journal of Educational Sciences*, *15*(3), 492–501. https://doi.org/10.18844/cjes.v15i3.4916

Wang, Y., Xie, B., Zhou, L., Wang, L., & Jin, H. (2025). The influence of learning interest on complex mathematical problem-solving ability: the mediating effect of classroom disruptive behavior and self-efficacy. *Frontiers in Psychology*, *16*(October), 1–12. https://doi.org/10.3389/fpsyg.2025.1638695

Yorganci, S. (2020). Implementing flipped learning approach based on 'first principles of instruction' in mathematics courses. *Journal of Computer Assisted Learning*, *36*(5), 763–779. https://doi.org/10.1111/jcal.12448

Yuliyanto, A., & Turmudi. (2020). Study based on the early mathematical ability of elementary student self-efficacy through the concrete-pictorial-abstract approach. *Universal Journal of Educational Research*, *8*(11), 5901–5912. https://doi.org/10.13189/ujer.2020.082224

Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012023

Zuo, S., Huang, Q., & Qi, C. (2024). The relationship between cognitive activation and mathematics achievement: mediating roles of self-efficacy and mathematics anxiety. *Current Psychology*, *43*(39), 30794–30805. https://doi.org/10.1007/s12144-024-06700-3