



Students' critical thinking across self-efficacy levels in STEM website-supported challenge-based differentiated learning

Fadhila Salvia Khairunnisa ^{1*}, Adi Satrio Ardiansyah ¹, Rini Wulandari ²

¹ Mathematics Education Department, Universitas Negeri Semarang, Central Java, Indonesia

² State Junior High School 39 Semarang, Central Java, Indonesia

* Correspondence: adisatrio@mail.unnes.ac.id

© The Author(s) 2026

Abstract

This study aims to examine the effectiveness of implementing Challenge-Based Differentiated Learning supported by a STEM website, analyze the influence of self-efficacy on critical thinking, and describe students' critical thinking skills in relation to self-efficacy. The research employed a mixed-methods approach, a sequential explanatory design, and simple random sampling. Class VIII B served as the experimental group implementing the CB-DL model, and VIII A as the control group implementing problem-based learning, with each group consisting of 33 students. The results showed that the CB-DL model was effective in improving critical thinking skills, as indicated by an increase in the average pretest score from 65.15 to 83.33 on the posttest and a Cohen's D of 0.57. In addition, self-efficacy has a significant effect on critical thinking skills with a value R^2 of 0.3542. Subjects with high self-efficacy met all six indicators of critical thinking skills, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. Those with moderate self-efficacy did not meet the self-regulation indicator, and those with low self-efficacy did not meet the explanation and self-regulation indicators. These findings confirm that the CB-DL supported by a STEM website, along with self-efficacy reinforcement, can optimize students' critical thinking skills.

Keywords: challenge-based learning; critical thinking skills; differentiated learning; self-efficacy; STEM website

How to cite: Khairunnisa, F. S., Ardiansyah, A. S., & Wulandari, R. (2026). Students' critical thinking across self-efficacy levels in STEM website-supported challenge-based differentiated learning. *Jurnal Elemen*, 12(1), 66-88. <https://doi.org/10.29408/jel.v12i1.32330>

Received: 16 September 2025 | Revised: 14 December 2025

Accepted: 11 January 2026 | Published: 19 February 2026



Introduction

Critical thinking skills are essential 21st-century competencies that equip students to prepare for global challenges (Guo et al., 2025). As a higher-order thinking skill, critical thinking requires systematic reasoning, analysis, and problem-solving abilities, particularly in mathematics learning (Algani, 2022). Critical thinking skills are higher-order cognitive abilities that include interpretation, analysis, evaluation, inference, explanation, and self-regulation, as stated by Facione (2015), and can be developed through structured learning processes. Strengthening critical thinking skills aligns with the goal of quality education in the Sustainable Development Goals (SDGs) of 2030, which emphasizes the continuous development of student competencies (Hamami, 2025).

Facts in the field show that the results of the PISA international assessment indicate that the critical thinking skills of Indonesian students are still relatively low. Only 18% of students were able to reach level 4, and almost none reached levels 5 or 6 (OECD, 2023). These levels represent the ability to reason, analyze, and solve complex problems (OECD, 2019). This condition aligns with the results of a preliminary study at SMP Negeri 39 Semarang, which found that the average critical thinking score of students was 32.59 out of a maximum score of 100.

Various learning models aim to enhance students' critical thinking skills; however, classroom practices often remain teacher-centered, resulting in limited student engagement (Leibovitch et al., 2025). Challenge-Based Learning (CBL) provides a relevant pedagogical approach by actively engaging students in solving contextual and meaningful challenges. However, it still tends to present learning uniformly and does not accommodate differences in student characteristics (Yoosomboon & Wannapiroon, 2015). Differentiated learning strategies offer learning that adapts to the characteristics and needs of students (Widodo et al., 2024). The integration of CBL and differentiated learning presents the Challenge-Based Differentiated Learning (CB-DL) model, which encourages active involvement while providing learning support in line with student development, in accordance with Vygotsky's Zone of Proximal Development (ZPD) theory (Ardiansyah et al., 2024; Paraniti et al., 2024).

To strengthen the implementation of CB-DL, the STEM approach serves as the foundation for developing critical thinking skills through interdisciplinary learning that links mathematical concepts and real-world problems (Fredy et al., 2025). This study developed a Canva-based website to facilitate the implementation of CB-DL by integrating Challenge-Based Learning syntax with differentiated learning strategies. The website supports process differentiation by providing a range of multimodal learning resources, including animated videos, audio materials, and student worksheets. It also supports product differentiation by allowing students to engage in STEM-based challenges aligned with their interests.

In addition, learning success depends on affective factors, including self-efficacy (Bandura, 1997). Self-efficacy is a construct developed within Bandura's social-cognitive psychology theory, which emphasizes that an individual's belief in their own abilities plays a crucial role in directing effort, persistence, and strategy when facing challenging problems (Wang et al., 2024). This belief influences the choice of strategy, level of effort, and persistence

of learners in the problem-solving process. Students with high self-efficacy tend to be more capable of solving problems, whereas students with low self-efficacy often exhibit a dependence on teacher assistance (Schraw et al., 2006). Additionally, self-efficacy serves as a metacognitive component in the problem-solving process, a crucial aspect of critical thinking skills (Wingard et al., 2022).

Previous researchers tended to examine critical thinking skills, website utilization, STEM approaches, challenge-based learning, differentiated learning, and self-efficacy separately, thus failing to provide an overview of the potential integration of all these components. Self-efficacy plays a role in supporting critical thinking skills through self-regulation and metacognition mechanisms (Schraw et al., 2006). The CBL model has been proven effective in improving critical thinking skills (Nawawi, 2017). The STEM approach encourages critical thinking skills through inquiry-based learning that stimulates reasoning, creativity, and independent learning (Thuneberg et al., 2018). Differentiated learning strategies significantly contribute to improving critical thinking skills by adapting instruction to the characteristics and needs of students (Lisnawati & Nirmala, 2024). Meanwhile, the use of websites as ICT-based learning media has the potential to strengthen the development of critical thinking skills (Fredy et al., 2025).

Based on the background, the novelty of this study lies in integrating Challenge-Based Learning, differentiated learning, the STEM approach, the use of websites as learning media, and self-efficacy into a single learning framework to develop students' critical thinking skills. The questions in this study are: (1) How effective is the implementation of the Challenge-Based Differentiated Learning model supported by a STEM website on students' critical thinking skills, (2) Is there an influence of self-efficacy on critical thinking skills, and (3) How are students' critical thinking skills described in terms of self-efficacy. Challenge-based learning positions learners as active subjects in solving contextual problems and aligns with Vygotsky's constructivist perspective, which emphasizes interaction, scaffolding, and the suitability of learning to learners' cognitive development stages (Georgara et al., 2025; Wilson, 2016). Therefore, integrating challenge-based learning, differentiated learning, technology use, and a learning environment that supports self-efficacy has the potential to enhance students' critical thinking skills.

Methods

This study employed a mixed-methods approach integrating quantitative and qualitative methods to obtain comprehensive and in-depth findings (Creswell, 2014). A sequential explanatory design was employed, with quantitative data collected and analyzed first, followed by the collection and analysis of qualitative data.

The study took place at SMP Negeri 39 Semarang and involved all eighth-grade students as the population. The researchers selected the sample through simple random sampling by choosing several groups that could be considered to represent the population (Cohen et al., 2007). Based on this procedure, Class VIII B served as the experimental group and received instruction through the Challenge-Based Differentiated Learning model supported by a STEM website ($n = 33$). In contrast, Class VIII A served as the control group and received

instruction using the Problem-Based Learning model ($n = 33$). The selection of these two classes was based on the equivalence of students' initial characteristics. In this study, self-efficacy served as the independent variable, while students' critical thinking skills served as the dependent variable.

Quantitative data

The study employed two instruments, a critical thinking test and self-efficacy questionnaire. The researchers designed the critical thinking test in the form of essay questions based on six indicators proposed by Facione (2015). Five mathematics education experts validated this instrument, yielding a CVI/Average score of 0.98. The researchers developed the self-efficacy questionnaire based on the framework proposed by Bandura (1997) and confirmed its reliability, with a Cronbach's α value of 0.741. The researchers analyzed quantitative data using RStudio to examine learning effectiveness through several statistical procedures, including a completeness test against the Learning Objective Achievement Criteria (KKTP), an improvement test to identify changes between pretest and posttest scores, a mean difference test to compare scores between groups, a test of improvement differences between the experimental and control groups, and an influence test to examine the effect of self efficacy on critical thinking skills.

To implement differentiated learning, the researchers administered a learning style test to identify students' learning preferences, and teachers used the results to group students according to their individual learning styles. The learning process incorporated differentiation in both process and product. In Learning Activities 1 and 2, teachers implemented process differentiation by presenting instructional materials in various formats: animated videos for visual learners, audio recordings for auditory learners, and student worksheets for kinesthetic learners. In Learning Activity 3, teachers applied product differentiation by aligning STEM-based challenges with students' interests.

Qualitative data

The researchers collected qualitative data through interviews with six students from the experimental group, selecting them using purposive sampling based on self-efficacy categories, namely high, moderate, and low, with two students representing each category. The researchers analyzed qualitative data using the interactive model proposed by Miles and Huberman, which consists of three stages: data reduction, data presentation, and conclusion drawing (Creswell, 2014). To ensure data validity, the researchers applied source triangulation and technique triangulation. The researchers conducted source triangulation by comparing information obtained from students with different levels of self-efficacy. In addition, the researchers applied the technique of triangulation by comparing data derived from test results and interview results.

Results

The effectiveness of implementing the challenge-based differentiated learning using STEM website on critical thinking skills

Before conducting further testing on the effectiveness of the learning model, the data were first analyzed to ensure that the assumptions of normality and homogeneity were satisfied. Hypothesis H_1 was accepted if the p – value was less than the significance level of 0.05. The effectiveness study examined four hypothesis, which are described in the following paragraph and summarized in Table 1.

The analysis of the first hypothesis test was conducted to determine whether the average critical thinking skills in the experimental group met the predetermined KKTP of 75 ($\bar{x}_{E_{posttest}} = 83.33, SD_{E_{posttest}} = 10.62, p - value = 0.00000414$). The normality test resulted in a p-value of 0.05293, indicating that the posttest data of the experimental group were normally distributed. Based on the RStudio output for the first hypothesis test, a $p - value = 0.00000414 < 0.05$ was obtained, indicating H_1 was accepted, meaning the average critical thinking skills of students in the experimental group was significantly higher than the KKTP.

The analysis of the second hypothesis test was conducted to determine the improvement in critical thinking skills in the experimental group after the treatment was applied ($\bar{x}_{E_{pretest}} = 65.15, SD_{E_{pretest}} = 15.65, \bar{x}_{E_{posttest}} = 83.33, SD_{E_{posttest}} = 10.62, p - value = 0.0000000001636$). The normality test resulted in a p-value of 0.05293 for the posttest data of the experimental group and a p-value of 0.1711 for the pretest data of the experimental group, indicating that both data sets were normally distributed. Based on the RStudio output for the second hypothesis test, a $p - value = 0.0000000001636 < 0.05$ was obtained, indicating H_1 was accepted, meaning there was a significant increase in the critical thinking skills of students in the experimental group following the treatment.

The analysis of the third hypothesis aimed to determine the difference in critical thinking skills between the experimental group and the control group. In testing the third hypothesis, comparing the posttest results of critical thinking skills between the experimental and control groups ($\bar{x}_{E_{posttest}} = 83.33, SD_{E_{posttest}} = 10.62, \bar{x}_{C_{posttest}} = 76.01, SD_{C_{posttest}} = 14.40, p - value = 0.0109$). The normality test resulted in a p-value of 0.05293 for the posttest data of the experimental group and a p-value of 0.13 for the posttest data of the control group, indicating that both data sets were normally distributed. The homogeneity test results showed $Pr(> F) = 0.3665 > 0.05$, indicating that the data came from populations with the same variance (homogeneous). Based on the RStudio output results for the third hypothesis test, a $p - value = 0.0109 < 0.05$ was obtained, indicating that H_1 was accepted, meaning that there is a significant difference with the experimental group demonstrating higher critical thinking skills than the control group. The magnitude of the treatment effect is indicated by a Cohen's d effect size of 0.57, which is in the moderate category. This is because the initial ability of the students was relatively high, so the increase that occurred was not too large.

The fourth hypothesis was analysed to compare the increase in critical thinking skills between the experimental and control groups ($E_{Gain} = 0.51, SD_{E_{Gain}} = 0.26, C_{Gain} = 0.40, SD_{C_{Gain}} = 0.29, p - value = 0.04431$). The normality test resulted in a p-value of 0.3879 for the experimental group's N-Gain data and a p-value of 0.07321 for the control group's N-Gain data, indicating that both data sets are normally distributed. The homogeneity test results showed $Pr(> F) = 0.355 > 0.05$, indicating that the data came from populations with the same variance (homogeneous). Based on the RStudio output results for the fourth hypothesis test, a $p - value = 0.04431 < 0.05$ was obtained, so H_1 was accepted, meaning that the increase in critical thinking skills in the experimental group is significantly higher than in the control group.

Table 1. Results of effectiveness tests

Hypothesis Test	<i>t</i>	<i>df</i>	<i>p - value</i>
Hypothesis 1	4.5064	32	0.00000414
Hypothesis 2	8.9391	32	0.0000000001636
Hypothesis 3	2.3512	64	0.0109
Hypothesis 4	1.7291	64	0.04431

Based on the hypothesis analysis, the results show that (1) the average critical thinking skills in the experimental group were higher than the KKTP of 75; (2) the posttest average in the experimental group was higher than the pretest average; (3) the experimental group scored higher in critical thinking skills than the control group; and (4) the increase in critical thinking skills was greater in the experimental group than in the control group. Therefore, it can be concluded that the Challenge-Based Differentiated Learning using STEM website is effective in improving students' critical thinking skills. These results support the research of Sardi et al. (2022) and Hidayah et al. (2024), which reported that this learning model effectively improves students' critical thinking skills.

The effect of self-efficacy on critical thinking skills

The test aimed to examine the effect of self-efficacy on critical thinking skills. Self-efficacy data were obtained from a questionnaire as the independent variable, while critical thinking skills were measured using the posttest as the dependent variable. The normality test showed that the posttest data for the experimental group had a $p - value$ of 0.05293 and the self-efficacy data had a $p - value$ of 0.1859. Since both values are greater than 0.05, the data are normally distributed. Based on this, the analysis was conducted using Rstudio, as presented in Table 2.

Table 2. Results of the effect of self-efficacy on critical thinking skills

Test	Results	Conslucion
Regression Equation	$a = 12.1534; b = 1.023$	$\hat{Y} = 12.153 + 1.023X$
Linearity Test	$p - value = 0.3481$	H_0 accepted
Significance Test	$Pr(> t) = 0.000259$	H_0 rejected
Coefficient of Determination (R^2)	Multiple R-squared: 0.3542	$R^2 = 35.42\%$

Based on Table 2, the regression equation is $\hat{Y} = 12.153 + 1.023X$, indicating that each one unit increase in self-efficacy is followed by increase of 1.023 in critical thinking skills. The linearity test resulted in $p - value = 0.3481 > 0.05$, showing a linear relationship between self-efficacy and critical thinking skills. The significance test gave $Pr(> |t|) = 0.000259 < 0.05$, indicating that self-efficacy has a significant effect on critical thinking skills. The coefficient of determination (R^2) of 0.3542 who's that 35.42% of the variance in critical thinking skills is explained by self-efficacy, while the remaining 64.58% is influenced by other factors.

Description of self-efficacy on critical thinking skills

High self-efficacy level

Interpretation

1. Target harian membakar kalori Dennis adalah 100 kalori. Dengan intensitas sedang Dennis membakar 15 kalori dlm 3mnt dan 30 kalori dalam 6mnt. Dennis berlori selama 60mnt

Analysis

2.

Waktu (mnt)	0	3	6	60	← x
Kalori	0	15	30	?	← y

Evaluation

3.

$$\frac{y_2 - y_1}{y_1 - y_2} = \frac{x_2 - x_1}{x_1 - x_2}$$

$$\frac{30 - 15}{15} = \frac{x - 3}{3}$$

$$\frac{15}{15} = \frac{x - 3}{3}$$

$$1 = \frac{x - 3}{3}$$

$$3 = x - 3$$

$$x = 6$$

Jadi, total kalori yang dibakar Dennis adalah $y = 5(60) = 300$ kalori.

Inference

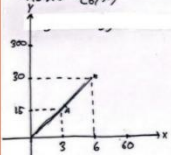
4. Total kalori yang dibakar Dennis dalam waktu 60mnt adalah 300 kalori

Explanation

5. Target harian membakar kalori Dennis adalah 100 kalori dan Dennis telah membakar 300 kalori yang berarti Dennis telah melampaui jumlah target hariannya.

Self-regulation

6. Titik A = (3, 15)
Titik B = (6, 30)



Dari grafik diatas kita dapat menentukan PGL dengan rumus $\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$ / $ax + by = c$

$$\frac{y - 15}{30 - 15} = \frac{x - 3}{6 - 3}$$

$$\frac{y - 15}{15} = \frac{x - 3}{3}$$

$$3(y - 15) = 15(x - 3)$$

$$3y - 45 = 15x - 45$$

$$3y = 15x$$

$$\frac{3y}{3} = \frac{15x}{3} = y = 5x$$

Jika sudah ditentukan PGL-nya hitunglah kalori yang dibakarnya dalam waktu 60mnt.
 $y = 5(60) = 300$ kal.
Jadi, dalam 60mnt Dennis membakar 300 kalori.

Translation:

- Dennis's daily target for burning calories is 100 calories. At a moderate intensity, Dennis burns 15 calories in 3 minutes and 30 calories in 6 minutes. If Dennis cycles for 60 minutes, how many calories does he burn?

Time (minutes) x	0	3	6	60
Calories y	0	15	30	?

- So, the total calories burned by Dennis is $y = 5(60) = 300$ calories.
- The total calories burned by Dennis in 60 minutes is 300 calories.
- Dennis's daily target for burning calories is 100 calories, and he has burned 300 calories, which means he has far exceeded his daily target.
- Point A = (3,15); Point B = (6,30)

From the graph above, we can determine the linear equation using the two-point formula. Once the linear equation is determined, calculate the calories burned in 60 minutes. So, in 60 minutes Dennis burns 300 calories.

Figure 1. Critical thinking test results of SE030

Figure 1 shows the results of the critical thinking test for subject SE030, which demonstrates the subject's ability to write down important information accurately, properly organize the steps to solve the problem using the concept of a straight line equation through two points, carry out the solution plan accurately, conclude the results accurately, explain the calculation results accurately, and be able to double-check accurately. The test results indicate that SE030 has demonstrated proficiency in the critical thinking ability indicators, including

interpretation, analysis, evaluation, inference, explanation and self-regulation. Through interviews, the subjects were able to explain the solution steps in detail as follows.

P : "Can you explain the problem and the information given?"

SE030 : "The problem is about calories burned while cycling. The data provided are 3 minutes = 15 calories, 6 minutes = 30 calories, and a daily target of 100 calories in 60 minutes."

P : "What is being asked, and do you understand the problem?"

SE030 : "It asks how many calories are burned in 60 minutes. I understood it easily, even though the text was long."

P : "What concept and steps did you use?"

SE030 : "I used the two-point straight line formula $\frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1}$ because it's more practical. I let time be x and calories be y , made a table, then applied the formula and got $y = 5x$. After that, I substituted $x = 60$ and the result was 300 calories."

P : "Did you encounter any difficulties during the process?"

SE030 : "No, everything was clear."

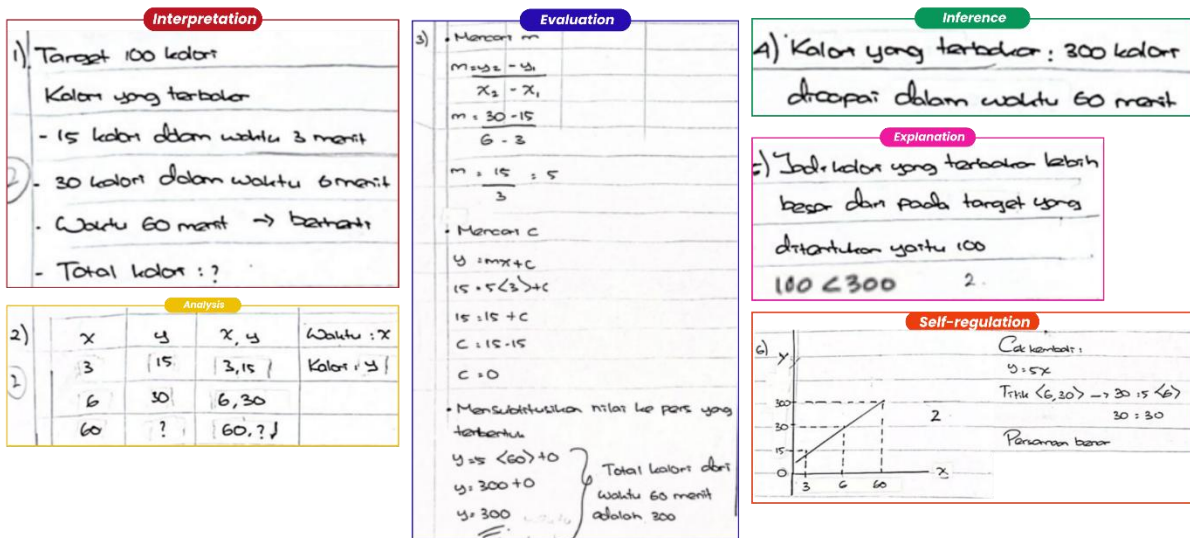
P : "How did you make sure your answer was correct?"

SE030 : "I drew a graph using the two points, and I matched, still $y = 5x$. When $x = 60$, the value is 300 calories."

P : "Are you confident about the entire process and your answer?"

SE030 : "I'm confident the answer is correct because I have checked it repeatedly." (answered very quickly without hesitation)

The subject was able to explain the steps to solve the problem systematically, choose an efficient strategy without needing to calculate the gradient first, and demonstrate high confidence in the process and the results achieved. The statement in the final interview illustrates the ability to self-regulate and carefully double-check to ensure the correctness of the answer. By considering the test results, interviews, and triangulation techniques, it can be concluded that subject SE030 meets the indicators of interpretation, analysis, evaluation, inference, explanation, and self-regulation.



Translation:															
1) Target: 100 calories			3) Substitute the values into the equation	6) Double-check:											
Calories burned:			formed	$y = 5x$											
-15 calories in 3 minutes			$y = 5(60) + 0$	Point $(6,30) \rightarrow 30 = 5(6)$											
-30 calories in 6 minutes			$y = 300 + 0$	$30 = 30$											
-60 minutes total time (stop)			$y = 300$	The equation is correct.											
Total calories : ?			The total calories burned in 60 minutes is												
2)	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><th>x</th><th>y</th><th>(x,y)</th></tr> <tr><td>3</td><td>15</td><td>(3,15)</td></tr> <tr><td>6</td><td>20</td><td>(6,30)</td></tr> <tr><td>60</td><td>?</td><td>(60,?)</td></tr> </table>	x	y	(x,y)	3	15	(3,15)	6	20	(6,30)	60	?	(60,?)	Time = x	4) The calories burned: 300 calories,
x	y	(x,y)													
3	15	(3,15)													
6	20	(6,30)													
60	?	(60,?)													
		Calories = y	were achieved in 60 minutes.												
			5) So, the calories burned are greater												
			than the target, namely 100, so $100 < 300$.												

Figure 2. Critical thinking test results of SE002

Figure 2 shows the results of the critical thinking test for subject SE002, indicating that the subject was able to write down important information accurately, organize the steps to solve the problem well using the concept of a straight line passing through one point by first finding the gradient, carry out the solution plan accurately, conclude the results accurately, explain the calculation results accurately, and perform a recheck accurately. The test results indicate that subject SE002 has demonstrated proficiency in the critical thinking ability indicators, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. Through an interview, the subject was able to explain the solution steps in detail as follows.

- P* : "Can you explain the problem and the information given?"
SE002 : "The problem is about calories burned while cycling. The calorie target, time, and data on calories burned at certain minutes are provided."
P : "What is being asked, and do you understand the problem?"
SE002 : "It asks for the total calories burned in 60 minutes, and I clearly understand the problem."
P : "What concept and steps did you use?"
SE002 : "I used the straight-line equation concept. I determined two points (3,15) and (6,30), then found the gradient $m = 5$, and formed the equation $y = 5x$. Substituting $x = 60$, the result is 300 calories."
P : "Did you encounter any difficulties during the process?"
SE002 : "A little difficulty finding the value of c , but I finally found $c = 0$."
P : "How did you make sure your answer was correct?"
SE002 : "I drew a graph to check the points and double checked by substituting into the equation."
P : "Are you confident about the entire process and your answer?"
SE002 : "I'm confident with this answer because the proses has been carried out systematically."

The subject can explain the steps to completion systematically, choose strategies that match their abilities, and show confidence in the process and results achieved. The statement in the final interview illustrates the ability to self-regulate because it involves checking each step to ensure the answer is correct. By considering the test results, interviews, and triangulation techniques, it can be concluded that subject SE002 meets the indicators of interpretation, analysis, evaluation, inference, explanation, and self-regulation.

Based on the descriptions of SE030 and SE002, a source triangulation was conducted, which demonstrated consistency in problem-solving and full attainment of the six indicators of

critical thinking skills. Both subjects were able to identify essential information in the problem (interpretation), develop an appropriate solution plan (analysis), perform accurate calculations (evaluation), draw correct conclusions (inference), explain the results clearly (explanation), and carry out self-checking effectively (self-regulation). The high self-efficacy level is concluded to meet all indicators of critical thinking skills, namely interpretation, analysis, evaluation, inference, explanation and self-regulation. The summary of source triangulation for the high self-efficacy level is presented in Table 3.

Table 3. Summary of source triangulation for high self-efficacy level

	Interpretation	Analysis	Evaluation	Inference	Explanation	Self-Regulation
SE030	✓	✓	✓	✓	✓	✓
SE002	✓	✓	✓	✓	✓	✓
Conclusion	✓	✓	✓	✓	✓	✓

Moderate self-efficacy level

Interpretation

1. 15 kalori = 3 menit
30 kalori = 6 menit
? = 60 menit
target harian 100 kalori

Analysis

2.
$$\begin{array}{|c|c|c|} \hline y & 15 & 30 \\ \hline x & 3 & 6 \\ \hline \end{array}$$

Evaluation

3.
$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{30 - 15}{6 - 3} = \frac{15}{3} = 5$$

$$y = mx + c$$
$$= 5x + c$$
$$= 60 \times 5$$
$$= 300$$

Inference

4. kesimpulannya, selama 3 menit membakar 15 kalori, dan 6 menit membakar 30 kalori, kalau 60 menit Dennis membakar 300 kalori telah melebihi targetnya yaitu 100 kalori.

Explanation

5. Sudah, malah melebihi target nya (300 lebih dari 100)

Translation:

1) 15 calories = 3 minutes	4) In conclusion, in 3 minutes Dennis burns 15 calories, and in 6 minutes he burns 30 calories. Therefore, in 60 minutes Dennis burns 300 calories, which exceeds his target of 100 calories.	5) Yes, he has even exceeded his target (300 is greater than 100).
30 calories = 6 minutes		
? = 60 minutes		
Daily target = 100 calories		

Figure 3. Critical thinking test results of SE020

Figure 3 shows the results of the critical thinking test for subject SE020, indicating that the subject was able to write down important information accurately, organize the steps to solve the problem well using the concept of a straight line passing through one point by first finding the gradient, carry out the solution plan accurately, conclude the results accurately, and explain the calculation results accurately. The test results indicate that subject SE020 has demonstrated proficiency in the critical thinking ability indicators, specifically interpretation, analysis, evaluation, inference, and explanation. Through interviews, the subject was able to explain the steps of the solution in detail as follows.

- P : "Can you explain the problem and the information given?"
 SE020 : "The problem is about calories burned while cycling. It is given that 15 calories are burned in 3 minutes, 30 calories in 6 minutes, and the daily target is 100 calories in 60 minutes."
 P : "What is being asked, and do you understand the problem?"
 SE020 : "It asks for the total calories burned in 60 minutes. I understand the problem well."
 P : "What concept and steps did you use?"
 SE020 : "I used the straight-line equation. I made a table with time (x) and calories (y), then calculated the gradient : $m = \frac{30-15}{6-3} = 5$. So the equation is $y = 5x$, and I substituted $x = 60$ to get $y = 300$."
 P : "Did you encounter any difficulties during the process?"
 SE020 : "I was a little confused finding the value of c, but I used 0 as in the example that was taught."
 P : "How did you make sure your answer was correct?"
 SE020 : "I didn't have time to double check, but I am confident in my answer."
 P : "Are you confident about the entire process and your answer?"
 SE020 : "Yes, fairly confident, even though I didn't check it again."

The subject demonstrated a good understanding of the context of the question, chose the appropriate solution strategy, and logically explained the process. However, the subject did not have time to double-check their answers, indicating that the aspect of self-regulation had not been achieved. However, because the subject did not have time to double-check, and it was also evident during the interview that they were unable to do. So, the self-regulation indicator has not been achieved. Taking into account the test results, interviews, and triangulation techniques, it can be concluded that subject SE020 meets the indicators of interpretation, analysis, evaluation, inference, and explanation.

Interpretation

1) Denis melakukan program diet dengan rutin bersepeda di Gore hauri. Target harian Denis adalah membakar 100 kalori.
 3 menit → 15 kalori
 6 menit → 30 kalori
 Waktu 60 menit bersepeda.
 Total kalori = 300 kalori.

Analysis

Waktu (x)	Kalori (y)
3 menit	15 kalori
6	30
60	300

Evaluation

3) $m = \frac{y_2 - y_1}{x_2 - x_1}$
 $= \frac{30 - 15}{6 - 3}$
 $= \frac{15}{3}$
 $= 5$

~~$y = mx + c$~~
 $y = 5x + c$
 $15 = 5(3) + c$
 $15 = 15 + c$
 $15 - 15 = c$
 $0 = c$
 $y = 5x + 0$
 $y = 5x$

$y = 5x$ waktu bersepeda.
 $= 5 \times 60$
 $= 300$

Inference

4) Denis membakar kalori sebanyak 300 dalam waktu 60 menit.

Explanation

5) Bersepeda Denis melebihi target kalornya, Target awal Denis 100 kalori tetapi Denis melebihi targetnya hingga 300 kalori.

Translation:

1) Dennis is on a diet program and regularly cycles in the afternoon. His daily target is to burn 100 calories.
 3 minutes → 15 calories
 6 minutes → 30 calories
 60 minutes → calories (then stop)

2) Time = x , calories = y

Time (x)	Calories (y)
3 minutes	15 calories
6	30
60	300

4) Dennis burns a total of 300 calories in 60 minutes.
 5) This means that Dennis exceeded his calorie target. Dennis's initial target was 100 calories, but he exceeded his target by 300 calories.

Figure 4. Critical thinking test results of SE012

Figure 4 shows the results of the critical thinking test for subject SE012, indicating that the subject was able to identify important information from the question, organize the steps to solve the problem correctly using the concept of a straight line equation from a single point and gradient, perform the calculations correctly, explain the results logically, and conclude the final answer correctly. The test results indicate that subject SE012 has demonstrated proficiency in the critical thinking skills of interpretation, analysis, evaluation, inference, and explanation. Through an interview, the subject was able to explain the steps of the solution in detail as follows.

P : “Can you explain the problem and the information given?”

SE012 : “The problem is about Dennis cycling, and the information given is 3 minutes = 15 calories, 6 minutes = 30 calories, the target is 100 calories, and he cycles for 60 minutes.”

P : “What is being asked, and do you understand the problem?”

SE012 : “It asks for the total calories in 60 minutes. I understand the problem.”

P : “What concept and steps did you use?”

SE012 : “I used the straight-line concept by making a table with x = time and y = calories. Then I calculated the gradient and formed the equation $y = 5x$. Substituting $x = 60$, the result is 300.”

P : “Did you encounter any difficulties during the process?”

SE012 : “No”

P : “How did you make sure your answer was correct?”

SE012 : “I just reread it to check.”

P : “Are you confident about the entire process and your answer?”

SE012 : “Yes, a confident miss but I don’t check it again.” (answered with slight hesitation)

SE012 demonstrates the ability to understand questions, develop appropriate strategies, and explain the solution process coherently and accurately. Although the subject double-checked their answers by rereading, their confidence in the final result still seemed slightly uncertain, indicating that the self-regulation indicator had not been achieved. By considering the test results and interviews, as well as triangulation techniques, it can be concluded that subject SE012 meets the indicators of interpretation, analysis, evaluation, inference, and explanation.

Based on the descriptions of subject SE020 and SE012, a source triangulation was carried out, which showed consistency in problem-solving and full achievement of five critical thinking indicators. Both subjects were able to understand the information in the problem

(interpretation), develop an appropriate solution plan (analysis), perform accurate calculations (evaluation), draw correct conclusions (inference), and explain the results clearly (explanation). However, the self-regulation indicator was not fully achieved, as SE020 did not recheck the answer and SE012 expressed some doubt even after rereading the solution. Therefore, it can be concluded that the moderate self-efficacy level was able to meet the indicators of critical thinking skills, namely interpretation, analysis, evaluation, inference, and explanation. The summary of source triangulation for the moderate self-efficacy level is presented in Table 4.

Table 4. Summary of source triangulation for moderate self-efficacy level

	Interpretation	Analysis	Evaluation	Inference	Explanation	Self-regulation
SE020	✓	✓	✓	✓	✓	-
SE012	✓	✓	✓	✓	✓	-
Conclusion	✓	✓	✓	✓	✓	-

Low self-efficacy level

Interpretation

1.) Target kalori → 100 kalori
 • 3 menit → 15 kalori
 • 6 menit → 30 kalori
 • waktu 60 → berhenti
 • total kalori 2

Evaluation

3.) mencari m $m: y: mx + c$
 $15 = 5 \times 3 + c$
 $15 = 15 + c$
 $c = 0$
 $y = mx + 0$
 $y = 5 \times 60$
 $y = 300$

Inference

4. $y = 300$ artinya denis bersepeda membakar 300 kalori

Analysis

2.)

waktu	kalori
3	15
6	30
60	

Translation:

1) Calorie target → 100 calories
 • 3 minutes → 15 calories
 • 6 minutes → 30 calories
 • 60 minutes → stop
 Total calories

Time	Calories
3	15
6	30
60	

3) Find the gradient (m)
 4) $y = 300$, meaning Dennis burns 300 calories by cycling for 60 minutes.

Figure 5. Critical thinking test results of SE007

Figure 5 shows the results of the critical thinking test for subject SE007, indicating that the subject was able to identify important information from the question, organize the steps to solve it correctly using the concept of a straight line equation from one point and a gradient, perform the calculations correctly, and conclude the results accurately. The test results indicate that subject SE007 has demonstrated proficiency in the critical thinking skills of interpretation, analysis, evaluation, and inference. Through an interview, the subject was able to explain the steps of the solution in detail as follows.

- P* : "Can you explain the problem and the information given?"
SE007 : "The problem is about Dennis following a diet program. The data given are 3 minutes = 15 calories, 6 minutes = 30 calories, the target is 100 calories, and he stops after 60 minutes."
P : "What is being asked, and do you understand the problem?"
SE007 : "It asks for the total calories in 60 minutes. I had some difficulty because the text was long."

- P : "What concept and steps did you use?"
 SE007 : "I used the gradient formula to make a straight line equation, then substituted the time value into the equation."
 P : "How did you solve the problem?"
 SE007 : "I calculated $m = 5$, then found $c = 0$, so the equation is $y = 5x$. After that, I substituted $x = 60$ and got 300 calories."
 P : "Did you encounter any difficulties during the process?"
 SE007 : "I had difficulty determining the values of x and y to calculate m ."
 P : "What is the final result, and what does it mean?"
 SE007 : "The result is 300, meaning Dennis burned 300 calories."
 P : "How did you make sure your answer was correct?"
 SE007 : "I didn't double-check because I wasn't sure if my steps were correct."

SE007 demonstrates a good understanding of the question's context, selects the appropriate solution strategy, and explains the process logically. However, the subject has not explain the results clearly and has not double-checked the answer, indicating that the aspects of explanation and self-regulation have not been achieved. Taking into account the test results and interviews, as well as triangulation techniques, it can be concluded that subject SE007 meets the indicators of interpretation, analysis, evaluation, and inference.

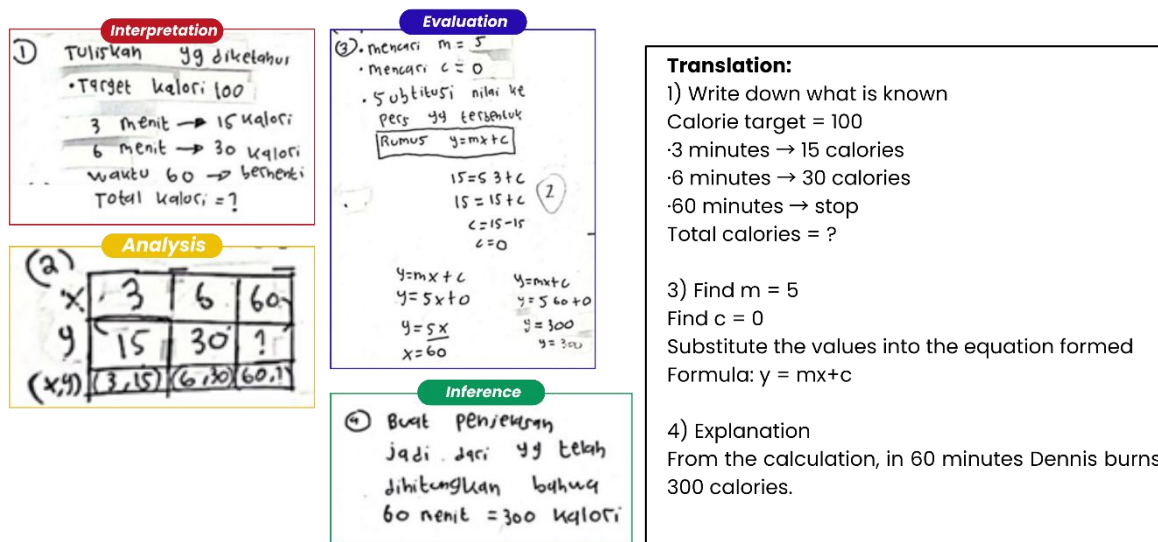


Figure 6. Critical thinking test results of SE025

Figure 6 shows the results of the critical thinking test for SE025, indicating that the subject was able to identify important information from the question, organize the steps to solve the problem correctly using the concept of a straight line equation from a single point and gradient, perform the calculations correctly, and conclude the results clearly. The test results indicate that subject SE025 has demonstrated proficiency in the critical thinking skills of interpretation, analysis, evaluation, and inference. Through an interview, the subject was able to explain the steps of the solution in detail as follows.

- P : "Can you explain the problem and the information given?"
 SE025 : "The problem tells a story about someone on a diet who regularly cycles in the afternoon. The calories burned, time, calorie target, and stopping time are given."
 P : "What is being asked, and do you understand the problem?"

- SE025 : *"It asks for the total calories burned until stopping time. I didn't have any difficulty (answered quickly)."*
- P : *"What concept and steps did you use?"*
- SE025 : *"I used the formula $y = mx + c$ because it's easy to remember"*
- P : *"How did you solve the problem?"*
- SE025 : *"I made a table $x = 3,6,60$ and $y = 15,30$. Calculated $m = 5$, then found $c = 0$ from $y = mx + c$. Substituting $x = 60$, got $y = 300$."*
- P : *"Did you encounter any difficulties during the process?"*
- SE025 : *"No (answered immediately)."*
- P : *"What is the final result, and what does it mean?"*
- SE025 : *"The result is 300 calories, meaning the total calories burned until stopping is 300 calories."*
- P : *"How did you make sure your answer was correct?"*
- SE025 : *"I didn't double check because I wasn't sure if my steps were correct."*

SE025 demonstrates a good understanding of the question's context, selects the appropriate solution strategy, and explains the process in a logical manner. However, the subject did not explain the results clearly and did not double-check the answer due to uncertainty. This indicates that the aspects of explanation and self-regulation have not been achieved. Taking into account the test results and interviews, as well as triangulation techniques, it can be concluded that subject SE025 meets the indicators of interpretation, analysis, evaluation, and inference.

Based on the descriptions of subject SE007 and SE025, a source triangulation was carried out, which showed consistency in problem-solving and full achievement of four critical thinking indicators. Both subjects were able to understand the information in the problem (interpretation), develop an appropriate solution plan (analysis), perform accurate calculations (evaluation), and concluded the results clearly (inference). However, the indicators of inference and self-regulation were not achieved. It can be conclude that the low self-efficacy level was able to meet the indicators of critical thinking skills, namely interpretation, analysis, evaluation, and inference. The summary of source triangulation for the low self-efficacy level is presented in Table 5.

Table 5. Summary of source triangulation for low self-efficacy level

	Interpretation	Analysis	Evaluation	Inference	Explanation	Self-regulation
SE007	✓	✓	✓	✓	-	-
SE025	✓	✓	✓	✓	-	-
Conclusion	✓	✓	✓	✓	-	-

Discussion

The effectiveness of the challenge-based on differentiated learning using STEM website on critical thinking skills

The Challenge-Based Differentiated Learning using a STEM website is proven to be effective in enhancing students' critical thinking skills, as it meets the average critical thinking skills in

the experimental group were higher than the KKTP of 75, the posttest average in the experimental group was higher than the pretest average, the experimental group scored higher in critical thinking skills than the control group and the increase in critical thinking skills was greater in the experimental group than in the control group. This is supported by the findings of Sardi et al. (2022) and Hidayah et al. (2024), who stated that challenge-based and differentiated learning encourages students to think more deeply when dealing with complex problems.

This success can be explained through Vygotsky’s constructivist learning theory, which emphasizes that optimal development occurs when students are guided according to their needs within the Zone of Proximal Development (ZPD) (Hidayah et al., 2024). The differentiated approach implemented in the learning process serves as a concrete form of this support. In this study, the teacher designed a flexible learning process based on students’ learning style in learning activities 1 and 2, and enriched the diversity of outcomes through product differentiation in learning activities 3.

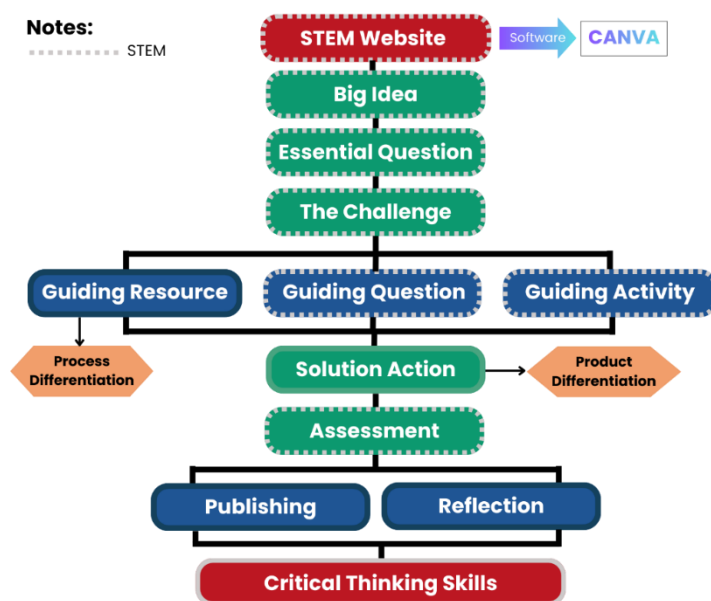


Figure 7. Learning framework

Critical thinking skills can be developed through the implementation of the Challenge-Based Differentiated Learning using STEM website. The integration of CBL with differentiated learning provides learning experiences that encourage students to solve the given challenges. Students are given the freedom to learn according to their learning style, a form of process differentiation, and to present their understanding according to their interests, a form of product differentiation, as shown in Figure 7. During the research, students were facilitated in understanding the material according to their learning styles. This is in line with the research by Retta et al. (2025), which states that learning tailored to the needs of students can improve critical thinking skills. Students with auditory learning styles understand the material through audio recordings, visual learners through animated videos, and kinesthetic learners such as student worksheets. This application is a form of process differentiation that aims to facilitate the understanding of student characteristics, thereby enhancing the comprehension of

information, identification of problems, and interrelationships between concepts, which ultimately strengthens critical thinking skills (Lisnawati & Nirmala, 2024). Meanwhile, product differentiation allows students to express their understanding through works that suit their interests, such as mind maps, posters, or booklets. This process trains them to evaluate information, select the most suitable form of presentation, and draw logical conclusions.

The implementation of differentiated learning creates a learning environment that encourages active student engagement in building understanding, choosing learning strategies, and engaging in reflection and decision making (Lisnawati & Nirmala, 2024; Tomlinson, 2003). In line with this, Jager et al (2025) states that differentiated learning can facilitate critical thinking skills through adjustments to learning content, processes, and products, which encourage students to analyze information, evaluate solution strategies, construct arguments, draw conclusions, and reflect on their thinking processes. Thus, the application of process and product differentiation in the CB-DL model supported by a STEM-based website can encourage the development of students' critical thinking skills.

The implementation of STEM strengthens the effectiveness of the website-assisted CB-DL model in improving critical thinking skills. Learning begins with contextual problems presented through the Big Idea syntax on the website, thereby encouraging cognitive engagement among students from the early stages of learning. In line with this, Thuneberg et al. (2018) state that STEM learning supports critical thinking skills through high-level cognitive engagement triggered by creativity, reasoning, and independent learning. This high-level cognitive engagement is systematically manifested through the application of CB-DL syntax integrated into the STEM website.

The manifestation of high-level cognitive engagement in learning is evident in the application of various STEM concepts within each learning activity. In the first learning activity, students learned about linear equations through the STEM context of technology, which was related to the use of electric bicycles. The second learning activity discussed gradients within the STEM context of technology, specifically related to aircraft crossings. Furthermore, the third learning activity examines the problem of linear equations in everyday life through the STEM context of science, namely, the salt content that affects the survival of tilapia fish. The integration of relevant STEM contexts with mathematical concepts makes learning more contextual, closer to real-world experiences, and enables students to gain a meaningful understanding (Pertiwi et al., 2024).

Learning then continues with Essential Question syntax, which guides students to ask in-depth questions related to the topic. Once completed, they move on to The Challenge, which requires real-world solutions. To answer these challenges, students are guided through Guiding Questions and Guiding Activities that direct the solution-finding process. During this process, students utilize Guiding Resources tailored to their individual learning styles. The next stage is Solution Action, where students produce products based on their individual interests and then publish them with accompanying presentations in the Publishing stage. This series of syntax forms a collaborative and contextual learning environment that encourages students to analyze problems, draw conclusions, and reflect on their thinking processes, allowing their critical thinking skills to develop.

The use of websites as ICT-based learning media has the potential to strengthen the development of students' critical thinking skills when integrated with active learning designs. Fredy et al. (2025) emphasize that ICT functions as a catalyst that strengthens pedagogical strategies in developing problem-solving, analytical, and argumentation skills. In STEM-based website-assisted CB-DL innovation, websites serve as a means of presenting context, sparking questions, and providing a medium for exploration and reflection that is integrated into every learning syntax. These findings are in line with Widodo et al. (2024), who state that the integration of differentiated learning, the STEM approach, and appropriate learning models is effective in improving students' critical thinking skills.

The effect of self-efficacy on critical thinking skills

Based on Table 2, the coefficient of determination (R^2) was found to be 0.3542 or 35.42%. This means that self-efficacy contributes 35.42% to critical thinking skills, while the remaining 64.58% is influenced by other variables not examined in this study. Thus, it can be concluded that the higher the level of self-efficacy students possess, the higher their ability to develop critical thinking skills. This finding is consistent with study of Prajono et al (2022), which stated that individuals with high self-efficacy levels are more confident in their ability to complete tasks, including those that require critical thinking skills (Hanifah & Agustini, 2012). These results are further reinforced by the relationship between the dimension of self-efficacy and the indicators of critical thinking skills as illustrated in Figure 8.

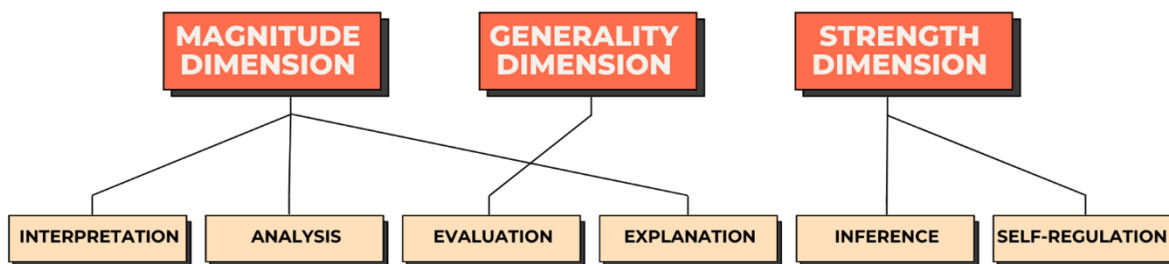


Figure 8. The relationship self-efficacy dimension and critical thinking skills indicators

Based on Figure 8, each dimension of self-efficacy has a different role in supporting critical thinking ability indicators. The magnitude dimension is related to the interpretation, analysis, and explanation indicators because students with a good level of magnitude can understand information, develop solution strategies, and explain the process coherently. The generality dimension is related to the evaluation indicator, because students can assess the accuracy of the steps and results obtained. Meanwhile, the strength dimension is related to the inference and self-regulation indicators because it encourages students to draw logical conclusions and double-check their answers.

Theoretically, the relationship between self-efficacy and critical thinking skills can be explained through the role of self-efficacy as a motivational factor that supports the functioning of higher-order cognitive processes through the mechanisms of self-regulation and metacognition. Schraw et al. (2006) explain that self-regulation and metacognitive awareness enable learners to plan, monitor, and evaluate thinking processes reflectively. In this context, self-efficacy does not directly shape critical thinking skills. However, it influences the level of

engagement, persistence, and consistency of learners in activating and maintaining critical thinking strategies when facing challenging tasks. However, empirical research shows that the role of critical thinking in relation to self-efficacy is complex, as indicated by Mildawani et al.(2022), who emphasize that critical thinking skills do not always function as direct mediators. Therefore, challenge-based learning, combined with positive feedback from teachers, is an effective strategy for increasing self-efficacy while strengthening students' critical thinking skills.

Description of critical thinking skills for each self-efficacy level in challenge-based on differentiated learning using STEM website

Subjects with high self-efficacy met all indicators of critical thinking skills, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. This finding aligns with the study of Widya et al (2023), which states that the higher the self-efficacy level, the more fully the critical thinking indicators are achieved. Subjects with high self-efficacy were able to accurately interpret information, develop problem-solving strategies, implement these strategies, draw logical conclusions, provide explanations related to the results obtained and recheck their thinking process. This achievement is driven by strong self-belief, perseverance, and good self-regulation abilities (Bandura, 1997).

Subjects with moderate self-efficacy were able to achieve five indicators of critical thinking, except for self-regulation. They were fairly capable of analyzing, evaluating, and drawing conclusions, but showed inconsistency in monitoring and reviewing their own thinking process. This indicates that they have good potential in critical thinking, yet still need guidance to develop more focused and controlled thinking skills. One contributing factor is their lack of confidence in the accuracy of their own work (Riyanto et al., 2019).

Subjects with low self-efficacy were only able to fulfill four indicators, with major weaknesses in explanation and self-regulation. They had difficulty explaining and did not recheck their own thinking processes. Indecisiveness and a tendency to give up easily were also apparent when facing challenges. This may be due to limited working memory capacity, as suggested by cognitive load theory, which can hinder learners' ability to evaluate their thinking processes (Hidayat & Noer, 2021; Sweller, 2024). In other words, limited self-efficacy affects the cognitive capacity to perform inference and self-regulation effectively.

These findings reinforce that self-efficacy is a crucial factor influencing the achievement of critical thinking skills. Therefore, the implementation of the challenge-Based on Differentiated Learning supported STEM website has great potential to enhance students' critical thinking skills. Effort to strengthen self-efficacy should be integrated into the learning process through positive feedback, gradually challenging assignments, and meaningful experiential learning.

Conclusion

The Challenge-Based differentiated Learning supported by a STEM website is effective in enhancing critical thinking skills. This effectiveness is evident in the increase in critical thinking skills after treatment compared to before treatment. This study also shows the influence of self-efficacy on students' critical thinking skills. Students with high self-efficacy can meet all critical thinking ability indicators. Students in the moderate category are currently unable to meet the self-regulation indicator. Meanwhile, students in the low category continue to struggle with meeting the explanation and self-regulation indicators. The implementation of this learning requires assistance to enable students to be actively involved. Teachers need to adjust their strategies based on the level of self-efficacy. For example, they can strengthen the strength dimension to improve self-regulation and strengthen the magnitude dimension to improve explanation in students with low or moderate self-efficacy, and maintain the magnitude, generality, and strength dimensions in students with high self-efficacy.

This study has several limitations, including a sample limited to one school, a relatively short intervention period, and no control over prior achievement that could influence the results. For future research, it is recommended to employ a longitudinal design or a randomized controlled trial (RCT), expand the sample to include several schools, and incorporate a teacher training module for more optimal implementation of CB-DL. Practical solutions that can be implemented include guiding teachers, integrating the CB-DL learning framework into online platforms, and developing gradual and reflective assignments to strengthen students' self-efficacy. With this approach, teachers can more easily design effective, differentiated, and digital-based challenge-based learning, while overcoming obstacles for learners with low self-efficacy.

Acknowledgment

The authors gratefully acknowledge the contributions of all individuals who have assisted in the preparation of this article. Appreciation is extended to the SMP Negeri 39 Semarang for granting permission to carry out this research. The authors also wish to thank everyone who has provided support for the successful completion of this study.

Declarations

- Conflicts of Interest : For the publication of this manuscript, the authors state that there are no conflicts of interest. The authors also confirm that all ethical requirements such as avoiding plagiarism, misconduct, making up or altering data, submitting or publishing the same work twice, and unnecessary repetition have been met.
- Generative AI Statement : Generative AI tools, such as Grammarly, are used to a limited extent to help refine grammar and improve clarity. All ideas, analysis, data interpretation, and scientific substance are entirely the author's own thoughts and responsibility.

- Funding Statement : The authors would like to express their gratitude to the Direktorat Penelitian dan Pengabdian Masyarakat, Kementerian Pendidikan Tinggi, Sains, dan Teknologi, for the funding provided through the Basic Research. With contract number is SK Nomor 089/C3/DT.05.00/PL/2025 and Perjanjian/Kontrak Nomor 181.2.6/UN37/PPK.11/2025
- Author Contributions : **Fadhila Salvia Khairunnisa:** Conceptualization, writing - original draft, analysis, editing, and visualization; **Adi Satrio Ardiansyah:** Supervision, Writing - review & editing, formal analysis, and methodology; **Rini Wulandari:** Validation and implementation.

References

- Algani, Y. M. A. (2022). Role , need and benefits of mathematics in the development of society. *Journal for the Mathematics Education and Teaching Practices*, 3(1), 23–29.
- Ardiansyah, A. S., Junaedi, I., Khoirunnisa, D. D., & Maharani, S. (2024). Challenge based on differentiated learning: upaya mengembangkan literasi numerasi dan memfasilitasi kebutuhan belajar peserta didik [Challenge-based differentiated learning: developing numeracy literacy and addressing students' learning needs]. *Prosiding Diskusi Panel Nasional Pendidikan Matematika*, 107–116.
- Bandura, A. (1997). *Self-Efficacy: The exercises of control*. W.H. Freeman and Company.
- Cohen, L., Manion, L., Lecturer, P., Morrison, K., & Lecturer, S. (2007). *Research Methods in Education* (6th ed). Routledge.
- Creswell, J. W. (2014). *Research Design: Qualitative, quantitative, and mixed methods approaches* (4th ed). SAGE Publications.
- Facione, P. A. (2015). *Critical Thinking: What it is and why it counts*. Measured Reasons LLC. www.insightassessment.com
- Fredy, L.-D., Oscar, B., & Ana, V. (2025). Pedagogical mediation with ICT for the development of critical thinking in primary education : A systematic review. *Thinking Skills and Creativity*, 60, Article 102085. <https://doi.org/10.1016/j.tsc.2025.102085>
- Georgara, A., Santolini, M., Kokshagina, O., Justine, C., Haux, J., Jacobs, D., Biwott, G., Correa, M., Sierra, C., Fernandez-marquez, J. L., & Rodriguez-aguilar, J. A. (2025). The role of AI in enhancing challenge-based learning participation experience and outcomes. *Computers and Education: Artificial Intelligence*, 8, Article 100388. <https://doi.org/10.1016/j.caeai.2025.100388>
- Guo, Y., Huang, L., Zhang, C., Li, Q., & Chen, M. (2025). ChatGPT in education: A systematic review of its impact on critical thinking skills and dispositions. *Thinking Skills and Creativity*, Article 102106. <https://doi.org/10.1016/j.tsc.2025.102106>
- Hamami, Y. (2025). Philosophy of mathematical practice and mathematics education : Cross-fertilization , dialogue and prospects. *Journal of Mathematical Behavior*, 78, Article 101208. <https://doi.org/10.1016/j.jmathb.2024.101208>
- Hanifah, N., & Agustini, R. (2012). Peningkatan self efficacy dan berpikir kritis melalui penerapan model pembelajaran inkuiri materi pokok asam basa kelas XI SMAN 9 Surabaya [Improving self-efficacy and critical thinking through the application of the inquiry learning model in the core subject of acids and bases for grade XI at SMAN 9 Surabaya]. *Unesa Journal of Chemical Education*, 1(1), 27–33. <https://doi.org/146125840>

- Hidayah, N., Kusmaryono, I., & Abdul Basir, M. (2024). Proses pembelajaran berdiferensiasi terhadap peningkatan kemampuan berpikir kritis pada materi operasi hitung aljabar [Differentiated learning process for improving critical thinking skills in algebraic calculation operations]. *Cartesian: Jurnal Pendidikan Matematika*, 4(1), 12–25. <https://doi.org/10.33752/cartesian.v4i1.6326>
- Hidayat, R. A., & Noer, S. H. (2021). Analisis kemampuan berpikir kritis matematis yang ditinjau dari self efficacy siswa dalam pembelajaran daring [Analysis of mathematical critical thinking skills reviewed from student self-efficacy in online learning]. *Media Pendidikan Matematika Program Studi Pendidikan Matematika FSTT UNDIKMA*, 9(2). <https://doi.org/https://doi.org/10.33394/mpm.v9i2.4224>
- Jager, L., Denessen, E., Cillessen, A. H. N., & Meijer, P. C. (2025). Instructional differentiation in secondary education: Teachers' actions and reasoning. *Teaching and Teacher Education*, 159, Article 105009. <https://doi.org/10.1016/j.tate.2025.105009>
- Leibovitch, Y. M., Beencke, A., Ellerton, P. J., McBrien, C., Robinson-taylor, C., & Brown, D. J. (2025). Teachers' (evolving) beliefs about critical thinking education during professional learning: A multi- case study. *Thinking Skills and Creativity*, 56, Article 101725. <https://doi.org/10.1016/j.tsc.2024.101725>
- Lisnawati, L., & Nirmala, S. D. (2024). The effectiveness of differentiated learning strategies on elementary students' mathematical critical thinking ability. *AL-ISHLAH: Jurnal Pendidikan*, 16(3). <https://doi.org/10.35445/alishlah.v16i3.5746>
- Mildawani, M. M. T. S., Murti, T. R., Maryatmi, A. S., & Abraham, J. (2022). A psychological model of competitive behavior: social comparison as a mediator of the critical thinking, self-efficacy, and adaptation ability prediction among college students. *Heliyon*, 8(12), e12205. <https://doi.org/10.1016/j.heliyon.2022.e12205>
- Nawawi, S. (2017). Developing of module challenge based learning in environmental material to empower the critical thinking ability. *Jurnal Inovasi Pendidikan IPA*, 3(2), 212–223. <https://doi.org/https://doi.org/10.21831/jipi.v3i2.15988>.
- OECD. (2019). *PISA 2018 assessment and analytical framework*. OECD Publishing.
- OECD. (2023). *PISA 2022 Results: Factsheets Indonesia* (pp.1-10). OECD Publishing.
- Paraniti, A. A. I., Redhana, I. W., Suardana, I. N., & Suma, K. (2024). Integration of challenge-based and differentiated learning: A Preliminary Study. *Jurnal Penelitian Pendidikan IPA*, 10(3), 1299–1308. <https://doi.org/10.29303/jppipa.v10i3.5245>
- Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through stem problem-based contextual learning: An integrated e-module education website with virtual experiments. *Journal of Baltic Science Education*, 23(4), 739–766. <https://doi.org/10.33225/jbse/24.23.739>
- Prajono, R., Gunarti, D. Y., & Anggo, M. (2022). Analisis kemampuan berpikir kritis matematis peserta didik smp ditinjau dari self efficacy [Analysis of junior high school students' mathematical critical thinking skills in terms of self-efficacy]. *Mosharafa: Jurnal Pendidikan Matematika*, 11(1), 143–154. <https://doi.org/10.31980/mosharafa.v11i1.694>
- Retta, A. M., Putri, R. I. I., Zulkardi, & Susanti, E. (2025). Enhancing critical thinking with realistic mathematics education: Insight from learning styles, thinking habits, and cognitive abilities. *Jurnal Elemen*, 11(3), 669–686. <https://doi.org/10.29408/jel.v11i3.30013>
- Riyanto, Waluya, & Mariani. (2019). Mathematics critical thinking reviewed from self-efficacy and motivation of learning in arias learning article info. *Journal of Primary Education*, 9(2), 243–250. <https://doi.org/https://doi.org/10.15294/jpe.v9i2.32690>
- Sardi, A., Palimari, P., & Rahmayani, S. (2022). Peningkatan kemampuan berpikir kritis peserta didik melalui challenge based learning [Improving students' critical thinking skills

- through challenge-based learning]. *Al-Irsyad Journal of Physics Education*, 1(2), 68-83. <https://doi.org/10.58917/ijpe.v1i2.31>
- Schraw, G., Crippen, K. J., & Hartley, K. (2006). Metacognition as part of a broader perspective on learning. *Research in Science Education*, 36, 111–139. <https://doi.org/10.1007/s11165-005-3917-8>
- Sweller, J. (2024). Cognitive load theory and individual differences. *Learning and Individual Differences*, 110, Article 102423. <https://doi.org/10.1016/j.lindif.2024.102423>
- Thuneberg, H. M., Salmi, H. S., & Bogner, F. X. (2018). How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module. *Thinking Skills and Creativity*, 29, 153–160. <https://doi.org/10.1016/j.tsc.2018.07.003>
- Tomlinson, C. A., Brighton, C., Hertberg, H., Callahan, C. M., Moon, T. R., Brimijoin, K., Conover, L. A., & Reynolds, T. (2003). Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted*, 27(2–3), 119–145. <https://doi.org/10.1177/016235320302700203>
- Wang, X., Huang, X., & Zhou, W. (2024). The effect of university students' self-efficacy on problem-solving disposition: The chained dual mediating role of metacognition disposition and critical thinking disposition. *Thinking Skills and Creativity*, 54, Article 101658. <https://doi.org/10.1016/j.tsc.2024.101658>
- Widodo, Y. B., Amri, M., Yustitia, V., Dwyarthi, N. D. M. S., Oktavuo, A., & Dirsia, A. (2024). The Effectiveness of the STEM-based Differentiation learning model on merdeka curriculum learning outcomes. *Indonesia Journal of Engineering and Education Technology (IJEET)*, 2(2), 173–181. <https://doi.org/10.61991/ijeet.v2i1.33>
- Widya, L. N., Sa'dijah, C., & Chandra, T. D. (2023). Kemampuan berpikir kritis siswa smp dalam menyelesaikan asesmen kompetensi minimum numerasi ditinjau dari efikasi diri. [Middle school students' critical thinking skills in completing minimum numeracy competency assessments reviewed from self-efficacy]. *Jurnal Paedagogy*, 10(4), 1189. <https://doi.org/10.33394/jp.v10i4.9170>
- Wilson, K. (2016). Critical reading, critical thinking: Delicate scaffolding in English for Academic Purposes (EAP). *Thinking Skills and Creativity*, 22, 256–265. <https://doi.org/10.1016/j.tsc.2016.10.002>
- Wingard, A., Kijima, R., Yang-yoshihara, M., & Sun, K. (2022). A design thinking approach to developing girls' creative self-efficacy in STEM. *Thinking Skills and Creativity*, 46, Article 101140. <https://doi.org/10.1016/j.tsc.2022.101140>
- Yoosomboon, S., & Wannapiroon, P. (2015). Development of a challenge based learning model via cloud technology and social media for enhancing information management skills. *Procedia - Social and Behavioral Sciences*, 174, 2102–2107.