



How do different learning models affect the vocational students' mathematical critical thinking and anxiety?

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Abstract

This study investigates how different learning models affect students' mathematical critical thinking skills while considering their levels of mathematics anxiety. In vocational education, mathematics is expected not only to enhance conceptual understanding but also to develop students' ability to critically solve real-world problems. To explore this issue, a 2×3 factorial experimental design was applied, involving two instructional models, namely CTL and PBL, as well as three categories of mathematics anxiety (high, moderate, and low). The study involved 44 tenth-grade students from SMK Muhammadiyah 1 Yogyakarta in the 2025/2026 academic year, selected through simple random sampling. Using a mathematical critical thinking test and a mathematics anxiety questionnaire, the data were collected and then analyzed with Aligned Rank Transform ANOVA due to violations of parametric assumptions. The findings reveal that there was no significant difference in students' mathematical critical thinking scores between the CTL and PBL groups ($p = 0.914$). Likewise, no significant differences were found across the levels of mathematics anxiety ($p = 0.380$). In addition, the interaction between learning models and mathematics anxiety was also not significant ($p = 0.591$). These results suggest that CTL and PBL lead to relatively similar levels of mathematical critical thinking performance, and that mathematics anxiety does not significantly differentiate students' outcomes in this context. Overall, the study highlights that both learning models yield comparable outcomes, while students' psychological conditions should still be considered in mathematics instruction.

Keywords: contextual teaching and learning, mathematical critical thinking, mathematics anxiety, problem-based learning, vocational high school

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INTRODUCTION

Vocational high schools (SMK), as part of the formal secondary education system, have an essential role in preparing graduates who are ready to face workforce demands (Sulistiani et al., 2022). Therefore, the success of education in vocational schools cannot be measured solely by students' mastery of technical skills, but also by their critical thinking and emotional intelligence, which support collaboration, communication, and adaptability to change (Rofiudin et al., 2024). However, mathematics learning in vocational schools still faces several challenges. Setiawati et al. (2021) reported that mathematics instruction in vocational schools has not sufficiently connected learning materials with real-life contexts. As a result, students often experience difficulties when applying mathematical concepts in everyday situations or in workplace contexts. This condition indicates the need for learning approaches that not only emphasize procedural knowledge but also help students construct conceptual understanding and develop

critical thinking skills. Such skills are considered essential for young people to navigate the challenges of the twenty-first century (Bouckaert, 2023).

One approach that can address these challenges is deep learning, which promotes meaningful student engagement in the learning process by emphasizing analysis, interpretation, and understanding rather than rote memorization. Through this approach, students are encouraged to critically examine problems and formulate solutions based on evidence and logical reasoning (Ester et al., 2023; Fitriani & Santiani, 2025). In addition, this approach also supports students in integrating new information with what they already know, leading to deeper understanding and improved critical thinking skills (Diputera et al., 2024). To optimize this process, appropriate learning models are needed to bridge abstract mathematical concepts with real-world contexts. This helps students understand the relationship between theory and its application.

By linking academic content to real-world contexts and encouraging active participation in learning, Contextual Teaching and Learning (CTL) represents an instructional model based on the principles of deep learning that helps students develop deeper and more meaningful understanding (Sundari & Suharto, 2025; Telaumbanua et al., 2026). In addition, CTL positions students as active learners who build their knowledge through meaningful learning experiences (Rosalina et al., 2024). A number of studies have shown that the implementation of CTL positively influences students' learning outcomes. Agustiningsih et al. (2024) found that implementing CTL in vocational schools increased students' focus and learning engagement because they could relate the learning materials to their daily lives. Similarly, Nurhanipah et al. (2025) reported that CTL enhances students' conceptual understanding by linking learning materials with real-life experiences. Students are encouraged to develop their understanding actively through activities such as discussions, practice exercises, and problem-solving. However, Helmi (2023) noted that some teachers still lack a comprehensive understanding of CTL implementation steps, which results in suboptimal use of the model in the learning process.

In addition to CTL, Problem-Based Learning (PBL) is another learning model that supports deep learning principles by allowing students to develop understanding, construct knowledge, and solve problems through active thinking processes and collaboration (Lisnawati et al., 2025). PBL introduces learning through contextual problems, guiding students to develop new understanding by connecting prior knowledge with new experiences, while simultaneously enhancing their critical thinking skills (Burhana et al., 2021; Darwati & Purana, 2021). Several studies have shown positive impacts of PBL implementation. Julianingsih et al. (2022) found that PBL improves students' understanding as they can relate the material learned to its application in everyday life. However, the success of PBL implementation strongly depends on the teacher's role as a facilitator. Teachers are required to design engaging learning activities, guide discussion processes, and develop comprehensive assessments to ensure optimal achievement of learning objectives (Masfufah et al., 2025).

Both CTL and PBL have the potential to develop students' critical thinking skills (Rukayah & Inganah, 2025; Sihite, 2023). By relating learning concepts to real-life problems, CTL helps students develop these skills through the analysis of situations and the identification of logical solutions (Gusrizal et al., 2024; Salma & Sumartini, 2022; Sarwari & Kakar, 2023). Likewise, PBL has been recognized as an effective model for strengthening critical thinking skills because its learning activities emphasize the resolution of contextual problems drawn from real-world situations (Faudziah & Budiman, 2023; Mareti & Hadiyanti, 2021). Critical thinking is the process of examining problems logically and reflectively to produce rational decisions or solutions (Setiawan et al., 2024; Susanti et al., 2023). In mathematics education, Susanti et al. (2023) explain that mathematical critical thinking comprises four main indicators: analyzing, problem-solving, drawing conclusions, and evaluating. Through the implementation of CTL and PBL,

students are expected to develop these four indicators as learning requires active engagement and reflection on their thinking processes.

In addition to learning models, students' psychological conditions, such as mathematics anxiety, may also influence their critical thinking abilities in mathematics learning (Musodiqoh et al., 2025). Mathematics anxiety can manifest in cognitive, affective, and physiological domains, which may lead to decreased concentration, reduced learning motivation, and lower self-confidence (Peker as cited in Azizah, 2021; Nurjanah & Alyani, 2021; Sholichah & Aini, 2022). Several studies have reported that high levels of mathematics anxiety tend to be associated with lower critical thinking skills among students (Hanifah & Miatun, 2024; Nugraheni & Pramugita, 2025). Therefore, efforts to improve students' mathematical critical thinking skills should not only consider the learning models used but also students' psychological conditions during the mathematics learning process.

Preliminary observations conducted at SMK Muhammadiyah 1 Yogyakarta indicate that mathematics learning has implemented the PBL model. However, several challenges remained, including limited student engagement and time constraints during problem exploration activities. Students' critical thinking skills also still need improvement, as indicated by their difficulties in analyzing information, organizing systematic solution steps, drawing conclusions, and re-evaluating their answers. Additionally, symptoms of mathematics anxiety were observed during the learning process, such as feelings of anxiety, low motivation, and difficulties in maintaining concentration. These conditions indicate that mathematics learning should not only aim to improve students' critical thinking abilities but also consider psychological factors that may influence their learning processes.

The effectiveness of CTL and PBL in mathematics learning has been confirmed by several studies. Sulnas et al. (2023) found that the CTL model improved students' critical thinking skills, while Hartono et al. (2023) reported that PBL affected students' critical thinking skills. In addition, Ghefira et al. (2024) found that CTL significantly influenced students' mathematics anxiety, whereas Hoffmann et al. (2024) reported that PBL affected both mathematics anxiety and mathematics learning outcomes. These findings indicate that CTL and PBL have been widely studied in relation to students' critical thinking skills and mathematics anxiety. Although these findings indicate the positive role of CTL and PBL in improving learning outcomes, most studies have focused on their effects separately.

However, the existing studies generally investigated these variables separately and did not directly compare CTL and PBL while simultaneously considering mathematics anxiety in relation to students' mathematical critical thinking skills. As a result, studies integrating cognitive and affective aspects in evaluating the effectiveness of CTL and PBL remain limited, particularly among vocational high school students. Considering that vocational education emphasizes the connection between conceptual understanding and real-world applications, learning models should not only be effective cognitively but also accommodate students' psychological conditions. Consequently, examining how learning models influence students' mathematical critical thinking skills while taking into account affective factors, including mathematics anxiety, is essential.

This study investigates three main aspects in vocational students: (1) the effect of the learning model on students' mathematical critical thinking skills; (2) the effect of mathematics anxiety on students' mathematical critical thinking skills; and (3) the interaction between the learning model and mathematics anxiety in influencing students' mathematical critical thinking skills.

Guided by this rationale, this study aims to investigate the effects of learning models on students' mathematical critical thinking skills, with mathematics anxiety treated as a moderating variable. The findings are expected to provide empirical insights into how learning models and mathematics anxiety, both individually and interactively, influence students' mathematical

critical thinking skills. In addition, the results may assist teachers in designing more contextual and responsive mathematics learning and serve as a reference for future studies in related fields.

RESEARCH METHOD

A 2×3 factorial research design was employed in this study, involving two types of learning models and three levels of mathematics anxiety. The design aimed to investigate the effects of learning models and mathematics anxiety on students' mathematical critical thinking skills in vocational high schools. The research procedure consisted of several steps, including selecting the sample, applying the learning models in each experimental class, administering a mathematical critical thinking test, distributing a mathematics anxiety questionnaire, and analyzing the collected data using a two-way ANOVA based on the Aligned Rank Transform method.

To select the sample, simple random sampling was used, giving every member of the population an equal chance of being chosen, thereby supporting representativeness and minimizing selection bias (Makwana et al., 2023; Noor et al., 2022). A total of 44 students from class X Animation and class X DKV 2 at SMK Muhammadiyah 1 Yogyakarta in the 2025/2026 academic year participated in the study. One experimental class was assigned to the CTL model, whereas the other experimental class was assigned to the PBL model.

In this study, the independent variables were the learning model (CTL and PBL) and mathematics anxiety, which was grouped into three levels: high, moderate, and low. The dependent variable was students' mathematical critical thinking skills. Based on this factorial structure, the first factor (X_1) represented the learning model with two levels, while the second factor (X_2) represented mathematics anxiety with three levels. The combination of these factors resulted in six treatment groups, namely A_1B_1 , A_1B_2 , and A_1B_3 for the CTL group, and A_2B_1 , A_2B_2 , and A_2B_3 for the PBL group, as presented in Table 1.

Table 1. Two-way ANOVA design^a

	Mathematics Anxiety		
	High (B_1)	Moderate (B_2)	Low (B_3)
Learning Model			
CTL (A_1)	A_1B_1	A_1B_2	A_1B_3
PBL (A_2)	A_2B_1	A_2B_2	A_2B_3

^aAdapted from Susanti & Susanti (2023)

Two research instruments were used in this study: a mathematical critical thinking test and a mathematics anxiety questionnaire. Mathematical critical thinking test was used to assess students' mathematical critical thinking skills, a test consisting of three essay items was administered. The development of the test was guided by four key indicators: analyzing, problem-solving, drawing conclusions, and evaluating. Prior to use, the instrument was reviewed by experts to establish its validity and subsequently tested for reliability to ensure consistent measurement. The students' scores were then grouped into three levels (high, moderate, and low) as presented in Table 2.

Table 2. Classification of students' mathematical critical thinking skills^a

No	Critical Thinking Score	Category
1	$66 \leq x \leq 100$	High
2	$33 \leq x < 66$	Moderate
3	$0 \leq x < 33$	Low

^aSource: Kartir et al. (2023)

Scores obtained by students on the mathematical critical thinking test are represented by x . Mathematics anxiety questionnaire consisted of 22 statements, developed based on indicators proposed by Sholichah & Aini (2022), covering cognitive, affective, and physiological aspects. Each statement used a five-point scale with a score range of 0–4. For positive statements, higher scores indicate lower levels of anxiety, while for negative statements, higher scores indicate higher levels of anxiety. Before use, the questionnaire was validated by experts and tested for reliability to ensure measurement consistency. The categories of students' mathematics anxiety levels were determined based on the mean score and standard deviation, as shown in Table 3.

Table 3. Scoring criteria for mathematics anxiety^a

Mean Score	Category	
	Positive	Negative
$x \geq \bar{x} + SD$	Low	High
$\bar{x} - SD \leq x \leq \bar{x} + SD$	Moderate	Moderate
$x \leq \bar{x} - SD$	High	Low

^aSource: Hajerina et al. (2023)

Data analysis in this study was conducted using a two-way analysis of variance (2×3 factorial ANOVA). This analysis was intended to examine three main aspects: (1) the effect of learning models on students' mathematical critical thinking skills, (2) the effect of mathematics anxiety on students' mathematical critical thinking skills; and (3) the interaction between learning models and mathematics anxiety on students' critical thinking skills in mathematics.

Before hypothesis testing was carried out, assumption tests were performed, including tests of normality and homogeneity of variance, to ensure that the data satisfied the requirements for parametric analysis. If the assumptions of parametric ANOVA were not met, a nonparametric Aligned Rank Transform (ART) ANOVA was applied in RStudio as an alternative method suitable for factorial designs.

RESULTS AND DISCUSSION

Data description

The data in this study were collected using two instruments, namely a mathematical critical thinking test and a mathematics anxiety questionnaire, both of which were administered after the learning process had been completed. The participants consisted of 44 students who were divided into two learning groups: one group received instruction using the CTL model, while the other group was taught using the PBL model.

The measurement results showed that students' mathematical critical thinking scores ranged from 0 to 100, with variations across both learning model groups and levels of mathematics anxiety. Overall, students' mathematical critical thinking skills tended to fall within the moderate range, although differences in achievement were observed. This variation indicates the potential influence of both learning models and students' psychological conditions on mathematical critical thinking skills. The distribution of students by learning model is presented in Table 4.

Table 4. Distribution of students based on learning models

Learning Model	CTL	PBL	Total
Number of Students	15	29	44

The distribution of students by mathematics anxiety level is shown in Table 5.

Table 5. Distribution of students based on mathematics anxiety levels

Mathematics Anxiety Level	High	Moderate	Low	Total
Number of Students	7	31	6	44

Assumption tests

The normality test resulted in a p-value of 0.036 at $\alpha = 0.05$. Because this value was below the specified significance level, the students' mathematical critical thinking data were considered non-normally distributed. Moreover, Levene's homogeneity test yielded a significance value of 0.008, indicating unequal variances across groups. Given the violation of both normality and homogeneity assumptions, a nonparametric factorial approach using ART ANOVA was considered more appropriate than data transformation due to its suitability for complex factorial designs.

Hypothesis testing

To examine the effects of the learning model, mathematics anxiety, and their interaction on students' mathematical critical thinking skills, hypothesis testing was conducted. The results of the ART ANOVA analysis are presented in Table 6.

Table 6. Results of ART ANOVA test

Source of Variation	Df	Error	F value	Sig.
Learning model	1	38	0.011772	0.91417
Mathematics anxiety	2	38	0.993474	0.37970
Learning model × mathematics anxiety	2	38	0.533405	0.59093

Interpretation of results

A significance value of 0.914 was obtained for the learning model factor at $\alpha = 0.05$. Since this value is greater than α ($0.914 > 0.05$), no statistically significant difference was found in the mean scores of students' mathematical critical thinking skills between the CTL and PBL groups. This indicates that the average mathematical critical thinking skills of both groups are similar. Based on the data obtained in this study, the learning model does not influence students' mathematical critical thinking skills. Accordingly, CTL and PBL provide comparable support for the development of students' mathematical critical thinking skills.

A significance value of 0.380 was obtained for the mathematics anxiety factor at $\alpha = 0.05$. Since this value is greater than α ($0.380 > 0.05$), no statistically significant differences were found in the mean scores of students' mathematical critical thinking skills across different levels of mathematics anxiety. This indicates that the average mathematical critical thinking skills of students with varying levels of mathematics anxiety are relatively similar. Based on the data obtained in this study, mathematics anxiety does not influence students' mathematical critical thinking skills. Accordingly, students with high, moderate, and low levels of mathematics anxiety demonstrate comparable performance in mathematical critical thinking skills.

Moreover, a significance value of 0.591 was obtained for the interaction between learning models and mathematics anxiety at $\alpha = 0.05$. Since this value is greater than α ($0.591 > 0.05$), no statistically significant interaction was found between the two variables. This indicates that students' mathematical critical thinking skills remain relatively consistent across different levels of mathematics anxiety in both the CTL and PBL groups. Based on the data obtained in this study, the interaction between learning models and mathematics anxiety does not influence students' mathematical critical thinking skills.

Discussion

The analysis indicates that there was no statistically significant difference between the learning models regarding students' mathematical critical thinking skills, suggesting that CTL and PBL implementation produced relatively similar outcomes. This finding shows that both learning models resulted in comparable levels of mathematical critical thinking skills among students. This result is consistent with previous studies indicating that both CTL and PBL emphasize active learning and engagement with contextual problems, which are essential components in developing students' critical thinking skills (Burhana et al., 2021; Darwati & Purana, 2021; Rosalina et al., 2024; Sundari & Suharto, 2025; Telaumbanua et al., 2026).

Furthermore, mathematics anxiety did not show a statistically significant effect on students' mathematical critical thinking skills in this study. This finding indicates that students with different levels of mathematics anxiety demonstrated relatively similar mathematical critical thinking skills, with no meaningful differences in their mean scores across anxiety levels. In general, Endika et al. (2025) emphasized that both cognitive and affective aspects are important components in mathematics learning to support the development of students' critical thinking skills. However, in this study, mathematics anxiety did not show a differentiating role in students' mathematical critical thinking skills. These results suggest that mathematics anxiety is not a determining factor in students' mathematical critical thinking performance within this study.

In addition, no interaction was found between learning models and mathematics anxiety. This indicates that the pattern of students' mathematical critical thinking skills was relatively similar across different levels of mathematics anxiety in both CTL and PBL groups. Thus, the relationship between learning models and students' mathematical critical thinking skills appears to be consistent across the mathematics anxiety levels examined in this study, indicating that both variables operate independently in influencing students' mathematical critical thinking skills.

CONCLUSION

These findings reveal that students' mathematical critical thinking skills do not differ significantly between those taught using CTL and those taught using PBL. Similarly, mathematics anxiety does not lead to statistically significant differences in these skills, and no interaction effect between the two variables was found. Overall, CTL and PBL produced comparable mean scores, while mathematics anxiety did not play a differentiating role in students' outcomes within the context of this study. This study is limited to the variables examined; therefore, future research is recommended to consider other affective factors that may influence students' mathematical critical thinking skills.

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DECLARATION

Author contribution

All authors contribute in the research and/or writing the paper, and approved the final manuscript.

Novi Putri Conceptualized the research idea, conducted the investigation, designed the methodology, analyzed the data, wrote the manuscript (introduction, method, results, discussion, and conclusion), and translated the article into English.

Uswatun Khasanah Supervised the research process, reviewed the methodology and data analysis, and provided suggestions and revisions to the manuscript.

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Conflict of interest

There are no conflicts of interest related to this study, as declared by the authors.

Ethics declaration

In accordance with ethical research standards, this study was conducted after obtaining permission for data collection from the relevant institutions. The authors also uphold the commitment of the International Journal on Education Insight (IJEI) in upholding high standards of professional conduct and ensuring integrity across all academic practices and activities.

The use of artificial intelligence

Only for language editing and improving manuscript clarity were generative artificial intelligence tools used. Full responsibility for the content of this article rests with the authors.

Additional information

No additional information is available.

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