



How PBL and CTL instructional models differ in affecting mathematical problem-solving skills

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Abstract

This research aimed to analyze the impact of the PBL and CTL instructional models on students' mathematical problem-solving skills, taking into consideration their learning interest levels. A quantitative experimental method with a 3×2 factorial design was applied. The study involved 43 eleventh-grade students from SMK Muhammadiyah 1 Yogyakarta, who were selected through random sampling and assigned into two groups. The first group consisted of 26 students taught using the PBL model, whereas the second group consisted of 17 students instructed through the CTL model. Data were obtained through two research instruments: a mathematical problem-solving test and a learning interest questionnaire. Before conducting hypothesis testing, the data satisfied the assumptions of normality and homogeneity and were analyzed using a two-way ANOVA. The analysis showed no significant effect of the instructional model on students' mathematical problem-solving ability (Sig. = 0.627 > 0.05). Likewise, learning interest was not found to significantly affect students' performance (Sig. = 0.310 > 0.05). Furthermore, no significant interaction effect was detected between instructional model and learning interest (Sig. = 0.651 > 0.05). The analysis demonstrated that students' learning interest did not interact with the instructional models in determining their mathematical problem-solving ability. These results imply that the influence of instructional models on problem-solving ability remains relatively stable across different levels of learning interest. Hence, future studies are recommended to explore additional variables that may affect students' mathematical problem-solving performance.

Keywords: contextual teaching and learning, learning interest, problem-based learning, problem-solving skills

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INTRODUCTION

Problem-solving is widely acknowledged as one of the key competencies that students must possess in mathematics education (Ndemo & Mtetwa, 2022; Sumaji et al., 2025). This skill is a central aspect of mathematics instruction, as emphasized in the Ministry of Education's National Regulation No. 22 of 2006 (Gr. Voskoglou, 2021; Harianja & Panjaitan, 2022; Nasution, 2022). It has been reinforced in the national educational standards to align with NCTM standards, which include problem solving, reasoning, justifying ideas, communicating, making connections, and representing (NCTM, 2000; Setiawan et al., 2021).

During the learning process, students are not only expected to master the lessons but must also apply their knowledge to address the problems presented. The importance of this skill lies in the fact that problem-solving demands students to understand the problem, design a solution plan, implement the selected strategy, and review the resulting outcomes (Jaenudin et al., 2025). Problem-solving skills play a crucial role in students' learning because, through this

experience, students are able to practice understanding issues in depth, analyzing them accurately, selecting the most appropriate strategies for resolution, performing calculations systematically, and evaluating the final results. Problem-solving skills are a fundamental component of the mathematics curriculum, as they allow students, during the learning process or while applying their knowledge, to integrate their knowledge and skills when facing complex challenges (Siswanto & Meiliasari, 2024).

In assessing mathematical problem-solving ability, several scholars have developed frameworks that serve as references for evaluation. George Pólya (1973) suggested that effective problem solving involves four sequential stages: understanding the problem, creating a plan, carrying out the plan, and checking the final result. Another widely recognized framework is the IDEAL problem-solving model introduced by John D. Bransford and Barry S. Stein, which consists of identifying the problem, defining objectives, exploring possible strategies, implementing the selected strategy, and evaluating both the results and the learning process. In addition, Stephen Krulik and Jesse A. Rudnick proposed a heuristic approach involving reading and comprehending the problem, exploring alternatives, choosing an appropriate strategy, and solving the problem (Siswanto & Meiliasari, 2024). Despite differences in terminology and the number of stages, these frameworks all emphasize a structured and reflective approach to problem solving. Accordingly, this study adopts four indicators that capture the common elements across the three models: (1) understanding the problem, (2) planning a solution strategy, (3) carrying out the plan, and (4) evaluating the solution obtained.

During approximately one month of initial conducting the School Field Introduction (PLP) program at SMK Muhammadiyah 1 Yogyakarta, the researcher conducted initial observations of the mathematics learning process in the classroom. To supplement this field data, the researcher also interviewed mathematics teachers and analyzed students' work on practice problems. Based on this data collection, findings indicated that students' mathematical problem-solving skills still require special attention. This was evident from several tangible challenges in the classroom, including students' difficulty in understanding the intent or essence of the problems presented. In addition, students were still unfamiliar with, and often hesitant to apply, the structured and systematic procedures required in solving mathematical problems.

This condition reveals a discrepancy between the expected level of mathematical problem-solving ability and the actual performance observed in classroom practice. Ideally, students are able to understand the problem, formulate a solution plan, apply solution steps, and evaluate the results independently and systematically. However, in reality, some students still face challenges at various stages. This imbalance highlights the need for more effective learning models to improve students' skills in solving mathematical problems.

Learning is an activity aimed at helping students acquire knowledge, skills, and understanding through a directed and systematic process. The primary goal of the learning process is to enhance conceptual understanding and develop students' thinking skills (Anjiani & Hasanudin, 2023). The success of this process can be measured by achieving educational goals (Zahroh & Hilmiyati, 2024). Given the expectations of 21st-century competencies, particularly Communication, Collaboration, Critical Thinking, and Creativity (4C), improving learning quality has emerged as a critical concern in contemporary education (Al-Jannah & Aly, 2022; Thornhill-Miller et al., 2023). It is important for teachers to take into account students' characteristics, the learning environment, and the intended learning objectives. In this regard, interactive and student-centered approaches, including deep learning, are increasingly essential in preparing students to deal with global challenges (Mailani et al., 2025; Rahayu et al., 2022).

Deep learning is an instructional approach that focuses on more meaningful information processing, encompassing critical, reflective, and creative thinking, as well as active problem-solving skills. Critical thinking in this context includes the ability to understand various information, analyze situations, formulate solutions to problems, and make appropriate and

responsible decisions in accordance with the problem context (Wahyudi et al., 2021). This approach focuses on linking new knowledge to students' prior experiences or existing knowledge (Mystakidis et al., 2021). Through contextual, collaborative, and reflective learning processes, Deep learning promotes students' engagement in higher-order thinking and discover solutions independently and meaningfully (Mailani et al., 2025). With these characteristics, deep learning significantly contributes to the enhancement of students' problem-solving abilities (Mailani et al., 2025).

To address these challenges, instructional models that reflect the principles of deep learning need to be implemented. A deep learning approach supports the development of 4C competencies by encouraging learning experiences that are contextual, collaborative, and reflective (Thornhill-Miller et al., 2023). Previous research findings suggest that instructional approaches such as Cooperative Learning, PBL, PjBL, and Discovery Learning are capable of supporting effective learning processes as well as improving students' 4C competencies (Rakhmawati et al., 2024).

Although these instructional models are all student-centered approaches, each of them offers different contributions to the development of mathematical problem-solving ability. Cooperative Learning emphasizes student collaboration, where learners work together, share ideas, and improve their conceptual understanding through interaction (Syah et al., 2024). In contrast, PBL engages students in investigating and solving authentic problems, creating opportunities to develop critical and reflective thinking skills through real-life contexts. Meanwhile, PBL requires students to engage in the exploration and resolution of real-life problems, which helps develop critical thinking and reflective abilities in meaningful contexts (Andika & Manurung, 2023). In contrast, Project-Based Learning (PjBL) positions students in activities involving the planning and completion of projects, thereby fostering systematic thinking skills and increasing their responsibility for their own learning process (Nurhamidah & Nurachadijat, 2023).

Discovery Learning emphasizes exploratory activities that allow students to construct knowledge independently (Annisa Rahman & Suwignyo Prayogo, 2025; M.Ramli & Mardhiyatirrahmah, 2025). Additionally, CTL supports deep learning practices by establishing connections between instructional materials and real-world experiences, thereby enhancing the meaningfulness of learning and placing students at the center of the learning process. Through CTL, students are not limited to understanding concepts in theory, but are also capable of applying them in real-life contexts (Muslihah & Suryaningrat, 2021).

Based on these various learning models, PBL and CTL were selected for this study because both have a strong connection to mathematical problem-solving skills. PBL positions a problem as the starting point of learning, thereby training students to understand the problem, gather information, formulate strategies, carry out solutions, and evaluate the results obtained (Rachmawati & Rosy, 2021). CTL facilitates students' understanding of mathematical concepts through the integration of real-life contexts, thereby enabling them to apply their conceptual knowledge more effectively in solving problems (Delita et al., 2026). Given these characteristics, PBL and CTL are considered relevant for developing problem-solving skills because they both emphasize active, contextual learning oriented toward the application of concepts (Ermayanti et al., 2025; Zulkarnain, 2023).

The findings of previous studies support the effectiveness of both instructional models. Andika & Manurung (2023) reported that the PBL model was more effective in enhancing students' mathematical problem-solving ability than instruction using a cooperative learning approach commonly referred to as "Student Teams Achieving Division" (STAD). Similarly, research Aulia & Hermansah (2024) indicates that the CTL model outperforms direct instruction in developing mathematical problem-solving ability.

Furthermore, students' interest in learning is considered a crucial internal factor influencing learning outcomes. Students' interest in learning reflects their inclination to actively participate in educational activities with full concentration and without any external pressure (Yuliati, 2021). In the context of mathematics learning, This interest plays an important role in strengthening motivation and commitment, as well as students' ability to grasp concepts and solve problems. Students who demonstrate a high level of passion for learning tend to adopt positive attitudes and actively seek solutions when faced with challenges. Therefore, teachers should create stimulating and meaningful learning environments to foster students' interest in learning (Anggraini et al., 2022).

Djamarah (2011) states that students' interest in learning can be observed through several indicators, namely enjoyment of learning activities, interest in the subject matter, active engagement in the learning process, diligence and enthusiasm in completing assignments, as well as perseverance and discipline in learning (Sucipto & Firmansyah, 2021; Putri & Adirakasiwi, 2021). In line with this, Herdiana, Rohaeti, & Sumarmo (2017) explains that indicators of learning interest include enjoyment, attraction to learning activities, attention to the material being studied, involvement in learning activities, as well as diligence, discipline, and the ability to manage one's study time.

Meanwhile, Safari, as cited in Asih & Ihsan Imami (2021), states that learning interest consists of a sense of enjoyment, interest in learning, attention during learning, and student engagement in learning activities. Although these perspectives use slightly different terminology, they share common elements, particularly in aspects such as enjoyment, interest, attention, engagement, and discipline in learning (Asih & Ihsan Imami, 2021). Therefore, this study adopts the indicators of learning interest based on Djamarah (2011), which include: (1) a sense of enjoyment, (2) interest in learning activities, (3) engagement in learning, (4) diligence and enthusiasm in completing tasks, and (5) perseverance and discipline in learning.

The state of mathematics instruction in the classroom indicates that students' interest in learning varies. Some students show interest in participating in the lessons, but there are still many students with low interest in learning mathematics. This is evident from the students' lack of attention to the teacher's explanations, low participation in discussions, and lack of perseverance in completing assigned tasks. When related to indicators of learning interest, these conditions indicate differences in the characteristics of students' learning interests in mathematics.

Several previous studies have recognized learning interest as a factor related to students' mathematical problem-solving ability (Anggraini et al., 2022, Maulina et al., 2022, and Yuliati, 2021). Learners with higher levels of interest in learning generally exhibit increased attention, stronger enthusiasm, active participation, and greater persistence during classroom activities. As a factor that may positively influence the learning process, learning interest was treated as an important variable in this study because it can support students in achieving a deeper understanding of mathematical concepts and improving their ability to solve problems.

Several prior studies have reported that the PBL model exerts a positive effect on students' mathematical problem-solving performance (Sembiring et al., 2025; Zulkarnain, 2023). This approach is based on problem-oriented learning activities that train students to think critically, analytically, and systematically in solving mathematical problems. Likewise, the CTL model has also been found to positively affect students' mathematical problem-solving skills by relating learning materials to real-world contexts encountered by students (Muslihah & Suryaningrat, 2021). Moreover, students' learning interest has been widely acknowledged as an important internal determinant of success in mathematics (Anggraini et al., 2022; Maulina et al., 2022; Yuliati, 2021).

However, these studies are generally carried out in a separate manner. Research on PBL and CTL mostly examines the effectiveness of each model independently in improving mathematical

problem-solving skills, while learning interest is commonly investigated as a single variable. Therefore, studies that combine the effects of PBL and CTL on mathematical problem-solving ability while simultaneously considering differences in students' learning interest within one unified analytical framework are still relatively scarce in the existing literature.

This research is conducted to investigate the influence of learning models on students' mathematical problem-solving ability while taking into account differences in students' levels of learning interest. These factors are incorporated into the analysis to achieve a more comprehensive explanation of the relationships among the variables. The study focuses on two student-centered instructional approaches, namely PBL and CTL, both of which emphasize applying knowledge in meaningful real-life situations. The findings of this study are expected to contribute empirically to the existing literature on the relationship between learning models, learning interest, and mathematical problem-solving ability, as well as to provide a basis for designing instructional strategies that are aligned with students' characteristics.

RESEARCH METHOD

A 3×2 factorial experimental design was applied in this study to investigate the relationships among the research variables. The participants consisted of 43 eleventh-grade students from SMK Muhammadiyah 1 Yogyakarta during the 2025/2026 academic year, selected using a random sampling procedure. They were allocated into two treatment groups, where 26 students were taught using the PBL approach and 17 students received instruction through the CTL approach. The study analyzed mathematical problem-solving ability as the dependent variable, whereas the type of instructional model and students' level of learning interest (high, moderate, and low) functioned as the independent variables.

The research was conducted in three sequential phases. The initial phase involved preparing the study by developing the research instruments and establishing their validity and reliability. The second phase consisted of implementing the learning treatments, with the PBL approach applied in the first experimental group and the CTL approach in the second. The final phase focused on collecting data through a test of mathematical problem-solving ability and a questionnaire measuring learning interest. Data collection relied on research instruments specifically developed according to the theoretical indicators of each variable under investigation. Two instruments were employed: a questionnaire to assess students' learning interest and a test to measure their mathematical problem-solving ability. Both instruments were constructed to ensure content validity and alignment with the objectives of the study, thereby providing data that accurately represent the actual conditions in the research setting.

The instrument used to measure students' learning interest consisted of a questionnaire containing 17 items adapted from (Aulia et al., 2021; Hermawan et al., 2022) and developed based on five indicators proposed by Djamarah (2011), namely: (1) feelings of enjoyment, (2) interest in learning activities, (3) engagement in learning, (4) diligence and enthusiasm in completing tasks, and (5) persistence and discipline in learning.

The response scale used a 4-point Likert scale with the following options: always (3), often (2), rarely (1), and never (0) for positive statements, and the reverse scoring for negative statements. Prior to data collection, the instrument underwent feasibility testing, including content validity analysis based on expert judgment and reliability analysis to assess item internal consistency. The questionnaire results were then categorized according to the percentage-based interpretation scale of learning interest, as presented in Table 1, following Arikunto (2010).

An essay-based test consisting of three function composition problems was employed to measure students' mathematical problem-solving ability. The test was constructed according to four dimensions of problem-solving ability, namely understanding the problem, planning a solution, implementing the selected strategy, and reviewing the obtained results.

Table 1. Learning interest interpretation scale

Percentage of Interest Score (%)	Criteria
$76 \leq x \leq 100$	High
$56 \leq x < 75,9$	Moderate
$0 \leq x < 55,9$	Low

Source: Arikunto (2010)

Prior to its implementation, the instrument was subjected to a feasibility assessment that included expert validation to establish content validity and reliability testing to ensure the consistency of the measurement results. After the data were collected, students' scores were classified according to the problem-solving ability criteria adapted from Mawardi et al. (2022), as shown in Table 2.

Table 2. Interpretation of mathematical problem-solving skills

Interval	Criteria
$80 \leq x \leq 100$	High
$60 \leq x < 80$	Moderate
$x < 60$	Low

Source: Mawardi et al. (2022)

Data analysis was conducted using a two-way analysis of variance (3×2 factorial ANOVA) to determine: (1) the effect of learning models on students' mathematical problem-solving ability, (2) the effect of learning interest on students' mathematical problem-solving ability, and (3) the interaction between learning models and learning interest on students' mathematical problem-solving ability (See Table 3). Before conducting the ANOVA, prerequisite tests were performed, including tests of normality and homogeneity of variance.

Table 3. Two-way ANOVA design

<i>Variabel X_2</i>	<i>Variabel X_1</i>	Learning Model	
		PBL (A_1)	CTL (A_2)
Interest in Learning	High (B_1)	($A_1 B_1$)	($A_2 B_1$)
	Moderate (B_2)	($A_1 B_2$)	($A_2 B_2$)
	Low (B_3)	($A_1 B_3$)	($A_2 B_3$)

RESULTS AND DISCUSSION

This study involved 43 students divided into two learning model groups: 26 students in the class using the PBL model and 17 students in the class using the CTL model. Additionally, based on learning interest, 16 students had moderate interest, and 27 had low interest (See Table 4).

Table 4. Distribution of students based on learning model and learning interest

Variable	Category	Number
Learning Model	PBL	26
	CTL	17
Interest in Learning	High	0
	Moderate	16
	Low	27

A series of statistical analyses was conducted to examine the effects of the PBL and CTL instructional models, which were reviewed in relation to differences in students' levels of learning interest, on their mathematical problem-solving abilities. The analysis began with testing the equivalence of students' initial abilities, followed by hypothesis testing. An independent-samples t-test was employed to determine whether there were differences in initial abilities between the two experimental groups. The results indicated a significance value greater than 0.05, showing that no statistically significant differences existed between the groups prior to the instructional treatment. Therefore, both groups were considered to have equivalent initial abilities.

After the implementation of the PBL and CTL instructional models, students completed a posttest to evaluate their mathematical problem-solving performance. The resulting posttest data were subsequently analyzed to examine the effects of the instructional model, students' learning interest, and the interaction between these variables on mathematical problem-solving abilities.

Since the required assumptions were met, the data were considered appropriate for further analysis using a two-way ANOVA. Normality and homogeneity of variance tests were conducted at a 0.05 significance level. The Kolmogorov–Smirnov test showed a significance value of 0.200, indicating that the data were normally distributed. In addition, Levene's test resulted in a significance value of 0.277, which is greater than 0.05, confirming the homogeneity of variance across groups.

Tests of Between-Subjects Effects

Dependent Variable: Mathematical Problem-Solving Ability

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	537,377 ^a	3	179,126	,449	,719
Intercept	49826,236	1	49826,236	125,002	<,001
LearningModel	95,432	1	95,432	,239	,627
LearningInterest	422,158	1	422,158	1,059	,310
LearningModel * LearningInterest	82,921	1	82,921	,208	,651
Error	15545,550	39	398,604		
Total	68310,880	43			
Corrected Total	16082,927	42			

a. R Squared = ,033 (Adjusted R Squared = -,041)

Figure 1. Result of the two-way ANOVA test

Figure 1 shows that the effect of the instructional models on students' mathematical problem-solving ability yielded a significance value of 0.627 (*Sig.* > 0.05). This result indicates that there is no statistically significant difference in the effect of the instructional models on students' mathematical problem-solving ability. Therefore, the findings do not provide sufficient statistical evidence to conclude that the applied instructional models lead to differences in students' mathematical problem-solving ability.

A lack of statistically significant difference does not imply the ineffectiveness of the PBL and CTL models in enhancing students' mathematical problem-solving ability. Rather, the findings indicate that both instructional approaches may contribute to students' problem-solving development to a comparable extent. This result is reasonable because PBL and CTL share several common characteristics, including a student-centered orientation, active learner participation, and opportunities for students to develop their own understanding through

inquiry-based activities and the exploration of authentic, real-life problems (Kamuntuan et al., 2026; Muhidin & Suparman, 2025).

On the other hand, the effectiveness of implementing the PBL and CTL models can be influenced by the conditions under which they are implemented. Both models require active student engagement as well as teachers' readiness to manage problem-based and real-world context-based learning (Muslihah & Suryaningrat, 2021; Siswanto et al., 2025). The findings of the current study stand in contrast to those of Muslihah & Suryaningrat (2021) and Siswanto et al. (2025) who demonstrated that instructional models had a significant impact on students' mathematical problem-solving abilities. This difference may be influenced by differences in the characteristics of the research subjects, experimental design, material studied, or learning implementation conditions.

A significance value of 0.310 ($Sig. > 0.05$) was obtained for the learning interest variable. This indicates that no significant differences in mathematical problem-solving ability were found among students with varying levels of learning interest. Consequently, the results do not offer sufficient statistical evidence to support that differences in learning interest are associated with variations in students' mathematical problem-solving performance.

Interest in learning is theoretically considered an internal factor that contributes to increasing students' attention, engagement, and motivation throughout the learning process, which in turn can enhance learning outcomes, including mathematical problem-solving skills (Sandi et al., 2024). Nevertheless, the present study did not identify a statistically significant effect of learning interest on students' mathematical problem-solving ability.

This absence of a significant effect may be attributed to the complexity of mathematical problem-solving skills, which are shaped by multiple influencing factors. In addition to learning interest, these factors include prior knowledge, learning motivation, learning strategies, and the learning environment (Artinta & Fauziyah, 2021). As a result, variations in learning interest do not necessarily lead to meaningful differences in students' mathematical problem-solving performance.

In contrast to previous research findings reported by Yuliati (2021), Anggraini et al. (2022) and Maulina et al. (2022), This study found no statistically significant influence of learning interest on mathematical problem-solving skills. These inconsistencies may be explained by differences in learner characteristics, measurement instruments, and the learning environments in which the studies were conducted.

Figure 1 shows that the interaction between the instructional model and students' learning interest produced a significance value of 0.651 ($Sig. > 0.05$). This result indicates that no statistically significant interaction effect was found between the learning model and students' learning interest on their mathematical problem-solving abilities. Accordingly, the influence of instructional models on mathematical problem-solving performance does not vary based on differences in students' levels of learning interest.

The lack of a significant interaction effect indicates that differences in the level of interest in learning do not increase or decrease the impact of teaching models on students' skills in solving mathematical problems. In other words, both the PBL and CTL model yield relatively similar results for students with varying levels of interest in learning. The results imply that the influence of instructional models on mathematical problem-solving ability does not vary across different groups of students.

Overall, the results of this study indicate that neither the instructional model, students' learning interest, nor the interaction between these factors contributed to significant differences in mathematical problem-solving ability. Nevertheless, these findings should not be interpreted as evidence that the instructional models employed were ineffective in promoting the development of such abilities. Rather, the results suggest that no significant differences were detected among the variables investigated. Therefore, future studies are encouraged to

examine additional factors that may contribute to students' mathematical problem-solving ability in order to gain a more comprehensive understanding of the factors influencing these skills.

CONCLUSION

Results from the data analysis indicate that neither the instructional model nor learning interest has a significant effect on students' mathematical problem-solving ability and outcomes. No significant interaction is found between the instructional model and learning interest, suggesting that learning interest does not alter the effect of instructional models on students' performance. Therefore, further research is recommended to investigate additional variables influencing mathematical problem-solving ability.

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DECLARATION

Author contribution

Each author has made contributions to the research process and the preparation of this manuscript and has agreed to the final version submitted for publication.

<i>Affiah Putri</i>	Formulating the research concept, carrying out the investigation, designing the methodology, and preparing the initial draft of the manuscript.
<i>Ardirani</i>	
<i>Uswatun</i>	Supervising the overall research process, validating the research methodology, evaluating the manuscript, and improving the data analysis procedures.
<i>Khasanah</i>	

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Conflict of interest

The authors state that there are no conflicts of interest related to this study.

Ethics declaration

The authors state that this study was carried out in accordance with established ethical standards and received approval from the relevant institution. All data were collected with appropriate consent.

The use of artificial intelligence

This study utilized artificial intelligence (AI) tools to assist in language refinement and writing improvement. However, all content, analysis, and conclusions are the authors' own work.

Additional information

Not available.

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