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The Effect of Differentiated Case-Based Learning on Students' Mathematical Problem-Solving Ability: The Role of Learning Readiness

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ABSTRACT This study examined whether differentiated learning using the Case-Based Learning (CBL) model was associated with higher mathematical problem-solving performance than Problem-Based Learning (PBL) and investigated differences across students' learning-readiness levels. The study employed a quasi-experimental nonequivalent control-group design involving Grade VIII students at SMP Negeri 1 Rancah, Indonesia, who studied straight-line equations. The analysis included 49 students with complete data: 24 in the experimental class and 25 in the control class. Data were collected using a mathematical problem-solving test and a learning-readiness questionnaire. Based on the reported group means, standard deviations, and sample sizes, the experimental class achieved a significantly higher posttest mean than the control class, $t(47) = 3.49$, $p = .001$, with a large effect size ($d = 1.00$). A one-way ANOVA within the experimental class also showed significant posttest differences among the high-, medium-, and low-readiness groups, $F(2, 21) = 57.81$, $p < .001$, $\eta^2 = .846$. Students with high readiness achieved the highest score on understanding the problem (98%), whereas re-examining the solution remained the weakest indicator across the readiness groups. These findings suggest that differentiated CBL can support mathematical problem solving; however, the effects of CBL and differentiation cannot be separated because the comparison class received a different instructional model.

Keywords: case-based learning; differentiated learning; learning readiness; mathematical problem solving.

INTRODUCTION

Mathematical problem solving is one of the central competencies that students are expected to develop. It requires students to understand a problem, formulate a plan, implement an appropriate strategy, and evaluate the resulting solution. These processes help students apply mathematical knowledge to nonroutine situations and support decision-making in everyday life (National Council of Teachers of Mathematics, 2000; La'ia & Harefa, 2021).

Students nevertheless continue to experience difficulties across these stages. Research has shown that students with lower mathematical ability may struggle to understand relevant information, develop a solution plan, implement the plan accurately, and re-examine their answers (Jaenudin et al., 2025). Interviews with mathematics teachers at SMP Negeri 1 Rancah indicated a similar pattern. Students were not accustomed to writing the known and required information, often needed teacher assistance when planning and implementing strategies, made calculation errors, and rarely checked their answers. Difficulties were particularly evident in straight-line equations, where students had to connect slope, points, and equations.

These conditions indicate a need for instruction that engages students with meaningful and varied problems. Case-Based Learning uses contextual cases as the basis for analysis, discussion, information gathering, and solution development. Its stages generally involve identifying a case, analyzing relevant information, determining a solution, and drawing conclusions. This structure can encourage students to discuss strategies and participate actively in the learning process (Dharmayanthi, 2023). Case-based tasks can also support problem-solving development when they require students to analyze unfamiliar situations rather than reproduce routine procedures (Agustiani et al., 2022). An open-access scoping review reported positive learner perceptions and equivalent or improved performance in several applications of online CBL, while also emphasizing limitations in study quality and reporting (Donkin et al., 2023). Although this evidence comes from medical education, it supports the careful use of authentic cases and structured facilitation in other learning contexts.

However, students do not enter the classroom with the same prior knowledge, skills, motivation, or readiness. Learning readiness is therefore relevant when teachers determine the complexity of content, the amount of guidance, and the expected learning product. Evidence indicates that readiness is related to mathematics learning outcomes (Sari & Ain, 2022; Syafi'i & Fauziyah, 2022). Differentiated instruction responds to such variation by adjusting learning content, processes, or products according to students' needs. Previous research has reported that differentiated learning can support mathematical problem-solving performance compared with nondifferentiated instruction (Pratiwi, 2024). International open-access research further indicates that differentiation can support students' academic self-concept and social inclusion, although its effectiveness depends on systematic planning and appropriate implementation (Pozas et al., 2021; Smale-Jacobse et al., 2019).

PBL provides a relevant comparison because it also positions students as active problem solvers who construct knowledge through inquiry, collaboration, and reflection (Yew & Goh, 2016). Indonesian studies have reported positive effects of PBL on mathematical problem-solving performance across elementary and secondary education (Marchy et al., 2022; Patunah et al., 2024; Sapoetra & Hardini, 2020; Ulva et al., 2020). Nevertheless, these studies generally examined PBL without combining case-based instruction and readiness-based differentiation.

Combining CBL with readiness-based differentiation may therefore provide students with contextual problem-solving activities while adapting instructional support to their needs. Students with lower readiness can receive more explicit prompts and scaffolding, whereas students with higher readiness can work with more complex cases and greater independence. Nevertheless, evidence concerning this combined approach in junior high school mathematics, particularly on straight-line equations, remains limited.

Accordingly, this study examined whether students taught through readiness-based differentiated CBL achieved different mathematical problem-solving performance from students taught through PBL. It also examined posttest differences among students with high, medium, and low learning readiness within the experimental class. Because the experimental and comparison classes received different instructional models, the study evaluates the combined differentiated-CBL approach rather than isolating the independent effect of either CBL or differentiation.

RESEARCH METHOD

This study employed a quantitative quasi-experimental approach with a nonequivalent control-group design. The population comprised 145 Grade VIII students in five classes at SMP Negeri 1 Rancah, Ciamis, Indonesia. Two intact classes were selected through cluster random sampling. Class VIII A was assigned as the experimental class and received readiness-based differentiated CBL, whereas Class VIII B served as the control class and received PBL without readiness-based differentiation.

The selected classes initially contained 28 and 27 students, respectively. Complete pretest and posttest data were available for 24 students in the experimental class and 25 students in the control class; therefore, the statistical analyses used 49 complete cases. The research design is presented in Table 1.

Table 1. Nonequivalent Control-Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_1	X_2	O_2

X_1: readiness-based differentiated CBL; X_2: PBL without readiness-based differentiation.

The intervention addressed straight-line equations over five meetings: one meeting for the pretest and readiness assessment, three instructional meetings, and one meeting for the posttest. Both classes studied the same topic, followed the same general learning objectives and instructional duration, and completed the same assessment framework. The primary difference was the instructional approach.

In the experimental class, learning readiness was measured using a 22-item Guttman-scale questionnaire comprising 12 positive and 10 negative statements related to physical, mental, emotional, motivational, and knowledge or skill readiness. The questionnaire was used to classify students into high-, medium-, and low-readiness groups. Content differentiation varied the complexity and scaffolding of the learning materials; process differentiation varied teacher guidance and prompts during case analysis; and product differentiation varied the expected form and level of students' solution presentations.

The mathematical problem-solving instrument consisted of two pretest and two posttest essay questions. Each item had a maximum score of 10 and was assessed using four indicators: understanding the problem, planning a solution, implementing the plan, and re-examining the solution (Jaenudin et al., 2025; Sa'diyah & Istiandaru, 2021). Mathematics education lecturers and teachers reviewed the instruments for content relevance, clarity, and alignment with the measured constructs.

Normality was examined using the Shapiro–Wilk test and homogeneity using Levene's test. Because the posttest assumptions were satisfied, the experimental and control classes were compared using an independent-samples t test. The test statistic, confidence interval, and effect size reported in this article were recalculated from the group means, standard deviations, and sample sizes presented in the source data. A one-way ANOVA was used to compare the posttest scores of the high-, medium-, and low-readiness groups within the experimental class. Bonferroni comparisons followed a significant omnibus test. Statistical significance was evaluated at $\alpha = .05$.

RESULTS AND DISCUSSION

Descriptive and Assumption-Test Results

Table 2 shows that the two classes had the same reported pretest mean. After the intervention, the experimental class obtained a higher posttest mean than the control class.

Table 2. Descriptive Statistics for Mathematical Problem-Solving Scores

Group	n	Pretest, M (SD)	Posttest, M (SD)
Experimental	24	6.88 (3.26)	14.50 (2.87)
Control	25	6.88 (3.28)	11.52 (3.10)

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The Shapiro–Wilk results supported normality for the pretest scores in the experimental ($p = .077$) and control ($p = .318$) classes and for the posttest scores in the experimental ($p = .290$) and control ($p = .087$) classes. Levene's test indicated homogeneous variances for both the pretest ($p = .778$) and posttest ($p = .093$) scores.

Comparison of Differentiated CBL and PBL

Based on the descriptive statistics in Table 2, the experimental class achieved a significantly higher posttest mean than the control class, $t(47) = 3.49$, $p = .001$. The mean difference was 2.98 points, with a 95% confidence interval of [1.26, 4.70]. Cohen's d was 1.00, indicating a large standardized difference.

The difference can be interpreted in relation to the instructional structure. CBL required students to engage with a contextual case, identify relevant information, analyze the situation, and determine a solution rather than immediately apply a formula. Differentiation adjusted task complexity and instructional support to students' readiness. This combination may have reduced the likelihood that tasks were too difficult for less-ready students or insufficiently challenging for more-ready students. This interpretation is consistent with evidence that CBL can promote active case analysis and that differentiated instruction can support mathematical problem solving (Dharmayanthi, 2023; Pratiwi, 2024; Pozas et al., 2021). It is also consistent with the broader PBL literature, which emphasizes collaborative inquiry and the active construction of problem-solving knowledge (Yew & Goh, 2016; Marchy et al., 2022).

The result should nevertheless be interpreted as the difference between two instructional packages: readiness-based differentiated CBL and PBL without differentiation. Because both the instructional model and the use of differentiation differed between classes, the design cannot determine whether the observed difference resulted from CBL, differentiation, or their combination. The use of intact classes and a posttest comparison also limits causal inference despite the identical reported pretest means.

Differences by Learning Readiness

The one-way ANOVA within the experimental class showed significant posttest differences among the readiness groups, $F(2, 21) = 57.81$, $p < .001$, $\eta^2 = .846$. Bonferroni comparisons indicated significant differences between the high- and medium-readiness groups (mean difference = 3.819, $p < .001$), high- and low-readiness groups (mean difference = 6.804, $p < .001$), and medium- and low-readiness groups (mean difference = 2.984, $p < .001$).

These findings indicate an association between learning readiness and posttest performance, not an experimentally established causal effect of readiness. Students with higher readiness may engage with more complex representations and require less scaffolding, whereas students with lower readiness may require explicit prompts, worked examples, and step-by-step guidance. This interpretation is compatible with previous evidence linking readiness to mathematics learning outcomes (Sari & Ain, 2022; Syafi'i & Fauziyah, 2022). The number, mean, and standard deviation for each readiness group should be reported in future studies to provide a more complete interpretation.

Achievement Across Problem-Solving Indicators

Table 3 presents the percentage achievement for the four problem-solving indicators. These percentages are descriptive and should not be interpreted as separate treatment effects.

Table 3. Percentage Achievement Across Problem-Solving Indicators

Indicator	Experimental Class						Control Class	
	High		Medium		Low		All Students	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Understanding the problem	33%	98%	24%	83%	33%	69%	37%	66%
Planning a solution	22%	75%	31%	75%	29%	54%	31%	50%
Implementing the plan	56%	76%	57%	76%	45%	57%	41%	72%
Re-examining the solution	19%	44%	19%	44%	21%	36%	23%	31%

Students with high readiness achieved the highest posttest percentage in understanding the problem (98%). Planning reached 75% in both the high- and medium-readiness groups, while implementing the plan reached 76% in both groups. Re-examining the solution remained the weakest indicator, reaching 44% in the high- and medium-readiness groups and 36% in the low-readiness group. The control class obtained 31% on this indicator.

The strong result for understanding the problem may be related to the case-analysis stage, which required students to identify known and required information. Differentiated prompts may also have helped students formulate and implement strategies suited to the complexity of each case. By contrast, students often stopped after obtaining an answer and did not routinely verify its reasonableness. Future implementation should therefore allocate explicit time and prompts for checking calculations, interpreting results, and validating solutions. Similar difficulty at the re-examination stage has been reported in previous research (Sa'diyah & Istiandaru, 2021).

CONCLUSION AND RECOMMENDATION

Students taught through readiness-based differentiated CBL obtained a higher posttest mean in mathematical problem solving than students taught through PBL. Based on the reported descriptive statistics, the difference was statistically significant and had a large effect size. Posttest performance also differed significantly among the high-, medium-, and low-readiness groups within the experimental class. Students performed most strongly in understanding the problem, while re-examining the solution remained the weakest indicator.

These findings support the use of contextual cases, readiness-based scaffolding, and differentiated task complexity in mathematics instruction. However, the findings should be interpreted cautiously because the study involved two intact classes from one school, used a short intervention, analyzed complete cases only, and changed both the instructional model and differentiation condition simultaneously. Future studies should report attrition reasons, group-specific readiness statistics, complete validity and reliability evidence, and intervention-fidelity information. Larger samples and designs using the same instructional model in both groups would help isolate the contribution of differentiation more clearly.

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