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Improving junior high school students' critical thinking skills through an ethnomathematics-based problem-based learning model with the teaching at the right level approach

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ABSTRACT

Background: Although previous studies have examined ethnomathematics, Problem-Based Learning (PBL), and the Teaching at the Right Level (TaRL) approach separately, empirical evidence on their integrated application in mathematics learning remains scarce. This study addresses this gap by evaluating the effectiveness of an ethnomathematics-based PBL model integrated with the TaRL approach to enhance junior high school students' critical thinking skills.

Purpose: This study aims to compare the effectiveness of the ethnomathematics-based Problem-Based Learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach and the conventional PBL model in improving the critical thinking skills of seventh-grade junior high school students.

Method: The study adopted a quantitative quasi-experimental approach and utilized a pretest–posttest control group design. This study employed cluster random sampling because the population consisted of intact seventh-grade classes. Rather than randomly selecting individual students, two existing classes were randomly selected from the population. One class (VII D; n = 28) was assigned as the experimental group, while another class (VII E; n = 29) served as the control group. Data were obtained through pre-intervention and post-intervention tests, observation records, and relevant documentation. To address the research objectives, the data were analyzed using descriptive and inferential statistical procedures, whereas hypothesis testing was performed using the Independent Samples t-test to determine the significance of differences between groups.

Findings: Findings: Students taught using the ethnomathematics-based Problem-Based Learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach obtained a higher mean critical thinking score (M = 49.58) than students taught using the PBL model without ethnomathematics and TaRL (M = 32.64). The difference was statistically significant (p = 0.006) and showed a

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moderate effect size (Cohen's d = 0.84), indicating that the integrated instructional model was more effective in improving seventh-grade junior high school students' critical thinking skills. The novelty of this study lies in integrating ethnomathematics-based PBL with the TaRL approach into a single instructional framework that combines culturally contextualized mathematics learning with differentiated instruction based on students' learning readiness.

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INTRODUCTION

21st-century education requires educators to prepare students to be academically and professionally successful individuals (Sufyadi et al., 2021). Students must have practical communication skills, critical thinking, creativity, and competitiveness in the contemporary global environment, they become a skilled and adaptive generation (Asyari & Arsana, 2023). Along with that, Critical thinking is considered a core competency for students, as it enables them to effectively respond to the intellectual demands and problem-solving challenges characteristic of twenty-first-century mathematics education. Given its central role in twenty-first-century education, it is important to clarify how critical thinking is conceptualized within mathematics education.

Critical thinking is generally defined as a higher-order cognitive process involving the ability to interpret, analyze, evaluate, infer, explain, and regulate reasoning when solving complex problems. Within mathematics education, critical thinking enables students to examine mathematical relationships, evaluate multiple solution strategies, justify conclusions, and make evidence-based decisions. Because critical thinking develops through meaningful learning experiences, an appropriate instructional framework is required to facilitate these cognitive processes.

Critical thinking has been widely recognized as one of the essential competencies for twenty-first-century learning. Critical thinking as purposeful and self-regulated judgment involving interpretation, analysis, evaluation, inference, explanation, and self-regulation. Critical thinking also as reasonable and reflective thinking focused on deciding what to believe or do. The integration of Problem-Based Learning (PBL), ethnomathematics, and the approach to Teaching at the Right Level (TaRL) can be theoretically explained through constructivist learning theory and sociocultural theory. PBL promotes active knowledge construction through authentic problem solving, encouraging students to analyze situations, formulate arguments, and evaluate alternative solutions. Ethnomathematics provides culturally meaningful learning contexts that connect abstract mathematical

concepts with students' everyday experiences, thereby facilitating conceptual understanding and reflective reasoning. Meanwhile, TaRL emphasizes differentiated instruction according to students' learning readiness, enabling learners to engage with mathematical tasks at an appropriate cognitive level while progressively developing higher-order thinking. Therefore, integrating these three instructional approaches is theoretically expected to create a learning environment that simultaneously promotes contextual understanding, cognitive engagement, and differentiated support, all of which contribute to the development of students' critical thinking skills.

In mathematics education, critical thinking is reflected in students' ability to identify mathematical problems, analyze information, evaluate solution strategies, construct logical arguments, justify conclusions, and reflect on their reasoning processes. Accordingly, this study adopts critical thinking indicators consisting of interpretation, analysis, evaluation, inference, explanation.

Mathematics learning provides students with opportunities to cultivate essential higher-order thinking skills, such as problem-solving, critical thinking, logical reasoning, and creativity, enabling them to respond effectively to the challenges of an increasingly interconnected global society(Firdaus & Maarif, 2022). Through mathematics learning at school, with the help of teachers, students can analyze, evaluate, and provide justification for the information received to make better decisions (Serepinah & Nurhasanah, 2023).

Problem-Based Learning (PBL) is widely recognized as an effective instructional strategy for fostering students' critical thinking skills. Grounded in constructivist learning theory, PBL actively engages students in solving authentic problems, thereby promoting analytical reasoning, reflective thinking, and knowledge construction (Meilasari et al., 2020). Previous studies consistently report that PBL enhances students' higher-order thinking, inquiry skills, self-directed learning, and self-confidence (Mayasari et al., 2022). Likewise, Darwati & Purana (2021), found that integrating ethnomathematics into the PBL framework further improved students' critical thinking by connecting mathematical concepts with culturally meaningful real-life contexts. Taken together, these studies suggest that PBL provides a strong foundation for developing critical thinking. However, previous research has generally examined PBL either as a standalone instructional model or in combination with a single complementary approach. Consequently, empirical evidence regarding the simultaneous integration of PBL, ethnomathematics, and the Teaching at the Right Level (TaRL) approach remains limited, particularly in the context of improving junior high school students' critical thinking skills.

Although PBL provides an effective problem-solving environment, its impact may be strengthened when mathematical problems are situated within students' cultural contexts. Ethnomathematics refers to the integration of mathematical ideas embedded in cultural

practices and everyday activities into mathematics learning (Ajmain et al., 2020). By connecting mathematical concepts with students' cultural experiences, ethnomathematics promotes meaningful learning and facilitates deeper conceptual understanding (Mahendra, 2017). More importantly, learning through cultural contexts encourages students to identify mathematical ideas, analyze relationships among concepts, evaluate alternative solution strategies, justify their reasoning, and draw logical conclusions. These cognitive processes directly correspond to the core components of critical thinking, including interpretation, analysis, evaluation, inference, and explanation. Furthermore, ethnomathematics encourages teachers to design culturally relevant learning experiences that foster active inquiry and reflective thinking, thereby creating richer opportunities for students to develop higher-order thinking skills (Wahyuni & Hasanudin, 2023).

In addition to providing culturally contextualized learning experiences, maximizing the effectiveness of Problem-Based Learning also requires instructional strategies that accommodate students' diverse learning readiness. Therefore, the effectiveness of an ethnomathematics-based Problem-Based Learning model can be further strengthened through the integration of the Teaching at the Right Level (TaRL) approach. Grounded in the principles of differentiated instruction, TaRL adapts learning activities to students' existing levels of knowledge and competency, thereby providing more equitable and meaningful learning opportunities (Listyaningsih et al., 2023). Unlike a standalone instructional approach, TaRL complements the Problem-Based Learning process by ensuring that students engage with culturally contextualized mathematical problems at levels appropriate to their learning readiness. Within this integrated framework, ethnomathematics provides authentic cultural contexts that make mathematical ideas meaningful, PBL facilitates collaborative inquiry and problem-solving activities, and TaRL differentiates instructional support according to students' current competencies. This complementary integration enables all students, regardless of their initial ability levels, to actively participate in problem solving, construct mathematical understanding, and progressively develop critical thinking skills. These arguments are supported by Suharyani et al. (2023), who reported that the TaRL approach provides teachers with the flexibility to adapt instruction according to students' learning needs. Therefore, integrating TaRL with ethnomathematics-based Problem-Based Learning offers a promising instructional framework for mathematics classrooms characterized by heterogeneous learning readiness.

Despite the theoretical advantages of these instructional approaches, their implementation in classroom practice remains limited. Preliminary classroom observations and interviews conducted at the research site revealed that students demonstrated relatively low critical thinking skills, indicating the need for instructional strategies that better promote higher-order thinking. Many students experienced difficulties in interpreting mathematical

problems and selecting appropriate solution strategies. Collaborative problem solving was also limited, as students tended to work individually rather than engaging in meaningful mathematical discussions. Furthermore, teachers had not yet implemented an ethnomathematics-based Problem-Based Learning model that connected mathematical concepts with students' local cultural experiences. Similarly, the Teaching at the Right Level (TaRL) approach had not been optimally applied, resulting in learning activities that were insufficiently differentiated according to students' varying levels of readiness. These observations indicate a clear practical need for a more contextualized and differentiated instructional model capable of supporting students' critical thinking development. Nevertheless, practical classroom challenges alone do not constitute sufficient justification for research. Educational research must also demonstrate that existing studies have not yet adequately addressed these challenges. Therefore, it is necessary to examine whether the current literature provides sufficient empirical evidence regarding instructional models that simultaneously integrate Problem-Based Learning, ethnomathematics, and the Teaching at the Right Level approach.

Previous studies consistently report that Problem-Based Learning improves students' critical thinking skills, whereas ethnomathematics enhances contextual understanding by integrating local culture into mathematics learning. Other studies have demonstrated that the Teaching at the Right Level (TaRL) approach improves learning outcomes by adapting instruction to students' readiness levels. However, these instructional approaches have largely been investigated independently. Existing studies rarely integrate culturally contextualized learning with differentiated instruction within a single Problem-Based Learning framework. Consequently, empirical evidence regarding whether the simultaneous integration of ethnomathematics and TaRL can generate greater improvements in students' critical thinking remains limited. Moreover, little is known about the effectiveness of this integrated instructional model in junior high school mathematics classrooms characterized by heterogeneous learning readiness.

Addressing this gap requires an instructional model that integrates these complementary approaches into a single coherent framework. Therefore, this study addresses the identified gap by integrating ethnomathematics-based Problem-Based Learning with the Teaching at the Right Level approach into a unified instructional framework. Unlike previous studies that examined these instructional approaches separately, the present study combines culturally contextualized mathematics learning and differentiated instruction to promote students' critical thinking skills. The novelty of this study lies in proposing and empirically testing an integrated instructional model that simultaneously accommodates students' cultural backgrounds and learning readiness.

This is evidenced by Hadi Saputro et al. (2020) which proves that the value of $t_{count} > t_{table}$ or $3.412 > 2.02$. Previous empirical evidence indicates that the ethnomathematics-based Problem-Based Learning model outperforms conventional lecture-oriented instruction in promoting student learning outcomes. Additionally, the integration of the Teaching at the Right Level approach within the PBL framework has been found to significantly enhance students' critical thinking skills, as demonstrated by an average achievement score of 80 and a classical mastery attainment of 78%. (Nadziroh et al., 2023).

Based on the identified theoretical and empirical gaps, the present study was designed to evaluate the effectiveness of this integrated instructional model. This study aims to evaluate the effectiveness of integrating ethnomathematics-based Problem-Based Learning and the Teaching at the Right Level approach in promoting the development of students' critical thinking skills. Specifically, this study assesses the impact of combining PBL with an ethnomathematics context and a TaRL approach that emphasizes critical thinking skills through instruction tailored to students' ability levels. It is anticipated that the use of this instructional framework will contribute to deeper conceptual comprehension and facilitate the cultivation of higher-order critical thinking abilities among students. The research questions arte does the integration of ethnomathematics-based Problem-Based Learning (PBL) with the Teaching at the Right Level (TaRL) approach significantly improve junior high school students' critical thinking skills compared with conventional Problem-Based Learning?, to what extent does the integration of ethnomathematics and the TaRL approach within the PBL framework contribute to students' critical thinking development?, and is there a statistically significant difference in critical thinking achievement between students taught using the ethnomathematics-based PBL with the TaRL approach and those taught using conventional PBL?

METHODS

A quantitative research approach with a quasi-experimental framework was employed in this study. The investigation utilized a pretest–posttest control group design to compare the effects of the instructional intervention. Participants were divided into an experimental group, which received the treatment, and a control group, which followed conventional instruction. To establish baseline equivalence and evaluate the impact of the intervention, both groups were administered a pretest before the treatment and a posttest upon its completion. The research was carried out in a junior high school setting.

The population of this study included all seventh-grade students enrolled in a junior high school during the second semester of the 2024/2025 academic year. Participants were selected through cluster random sampling, resulting in two representative classes. Cluster random sampling was employed because the school assigned students to intact classrooms

at the beginning of the academic year. Random assignment of individual students was therefore not feasible. Class VII D, consisting of 28 students, was designated as the experimental group, whereas Class VII E, comprising 29 students, served as the control group. The participants were 57 seventh-grade students enrolled in a public junior high school in Yogyakarta, Indonesia, during the second semester of the 2024/2025 academic year. The students were approximately 12–13 years old. The experimental class consisted of 28 students (15 females and 13 males), whereas the control class consisted of 29 students (16 females and 13 males). The school implements the Indonesian national curriculum and serves students from diverse socio-economic backgrounds. Prior to the intervention, both classes had received similar mathematics instruction from teachers with comparable teaching experience.

Before instruction, students completed a diagnostic assessment. Based on the results, students were categorized into three learning readiness levels:Level 1 (basic), Level 2 (intermediate), Level 3 (advanced). Learning tasks were differentiated according to these levels. Students in the basic group received more teacher guidance and scaffolded worksheets, while advanced students were assigned more open-ended mathematical investigations. The intervention was conducted over six weeks consisting of twelve mathematics lessons (2 × 40 minutes per lesson). The instructional intervention focused on quadrilateral perimeter and area, including squares, rectangles, parallelograms, rhombuses, trapezoids, and kites.

Ethnomathematical contexts were derived from traditional Yogyakarta cultural artifacts, including batik motifs, Joglo house architecture, traditional market layouts, and local handicrafts. These cultural contexts were embedded into mathematical problems involving perimeter and area of quadrilaterals. Students explored mathematical concepts through authentic cultural objects before generalizing them into formal mathematical representations.

To ensure intervention fidelity, all instructional sessions were observed using a learning implementation checklist. The average implementation fidelity reached 94%, indicating that the learning procedures were implemented consistently throughout the intervention. Permission to conduct the study was obtained from the school principal, mathematics teacher, students, and parents.

Data collection was carried out using observations, documentation, and achievement tests. Classroom observations were conducted to identify challenges and learning conditions within mathematics instruction. Documentation in the form of photographs and field records was compiled during the implementation of the ethnomathematics-based Problem-Based Learning model integrated with the Teaching at the Right Level approach. Students' critical thinking skills were evaluated through pretest and posttest assessments

administered before and after the intervention, enabling the measurement of learning gains resulting from the instructional treatment. The test instrument was validated through expert judgment to ensure content validity. Construct validity was examined by mapping every item to Facione's critical thinking framework consisting of interpretation, analysis, evaluation, inference, and explanation. The reliability of the test instrument was assessed using Cronbach's Alpha coefficient. Descriptive statistics were used to analyze student performance. Normality was tested using the Shapiro Wilk test. Homogeneity was assessed using Levene's test. Hypothesis testing was conducted using the Independent Samples t-test to determine the significance of differences between groups. Prior to this analysis, descriptive statistics were generated to summarize the pretest and critical thinking assessment data, including the mean, standard deviation, minimum value, and maximum value for both the experimental and control groups. Furthermore, several prerequisite tests, comprising normality, homogeneity, and balance analyses, were performed to ensure that the assumptions underlying parametric statistical procedures were satisfied. The critical thinking test consisted of three open-ended items representing five indicators of critical thinking (interpretation, analysis, evaluation, inference, and explanation). Content validity evaluated by three experts produced Aiken's V values ranging from 0.83 to 0.92, indicating high validity. Reliability analysis yielded Cronbach's Alpha coefficients of 0.666 (pretest) and 0.613 (posttest), suggesting acceptable internal consistency.

Content Validity

The content validity of this research instrument was assessed by three experts, namely two mathematics education lecturers and one mathematics teacher. Table 1 summarizes the outcomes of the content validity evaluation conducted by three independent experts.

Table 1.

Content Validity of Pre-Test Instrument

Question Item	V
Item_01	0,91667
Item_02	0,83333
Item_03	0,91667

Table 2.

Content Validity of Post-Test Instrument

Question Item	V
Item_01	0,91667
Item_02	0,83333
Item_03	0,91667

Based on the output above, the results of the content validity analysis of the pretest and posttest measurement instruments fall into the high category ($V > 0{,}8$). In the pre-test question, the content validity analysis revealed that Item 1 attained a coefficient value of 0,91667., item number 2 is 0,83333, and item number 3 is 0,91667. Similar results were also shown in the validation results of the post-test question instrument, where the validity value of item number 1 is 0,91667, item number 2 was 0,83333, and item number 3 was 0,91667. Thus, it can be concluded that both instruments show a high level of validity and the instrument can be employed to evaluate students' critical thinking abilities.

Reliability

The reliability coefficients of the research instrument were calculated using SPSS version 25, and the results are summarized in the following table.:

Table 3.

SPSS Output of Pre-Test Instrument Reliability Test

Cronbach's Alpha	N of Items
.666	3

Table 4.

SPSS Output of Post-Test Instrument Reliability Test

Cronbach's Alpha	N of Items
.613	3

The reliability testing produced Cronbach's Alpha coefficients of 0.666 for the pretest instrument and 0.613 for the posttest instrument. These findings suggest that both instruments demonstrate an acceptable level of internal consistency, supporting their suitability as reliable measures of students' critical thinking skills.

Data Description

To establish baseline equivalence between groups, students' initial abilities were assessed through a pretest administered before the treatment phase. The resulting descriptive statistics for experimental and control groups are reported in table 5.

As presented in Table 5, both the experimental and control groups achieved the same maximum pretest score of 48. However, the minimum score in the experimental group was 6, whereas the control group recorded a lower minimum score of 2. The mean pretest score of the experimental group (24.92) exceeded that of the control group (16.16). In addition, the experimental group exhibited a higher standard deviation (13.081) than the control group (10.723), indicating greater variability in students' initial performance. Overall, these findings suggest that although the experimental group demonstrated a higher average level

of prior achievement, its score distribution was more dispersed than that of the control group. While on the critical thinking skills test on table 6.

Table 5.

Descriptive Statistics of Students' Pretest Critical Thinking Scores in the Experimental and Control Groups

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Experiment Class Pre-Test Score	26	6	48	24.92	13.081	171.114
Control Class Pre-Test Score	25	2	48	16.16	10.723	114.973

Table 6.

Descriptive Statistics of Students' Posttest Critical Thinking Scores in the Experimental and Control Groups

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Experiment Class Post-Test Score	26	8	96	49.58	23.873	569.934
Control Class Post-Test Score	25	10	73	32.64	15.198	230.990

As shown in Table 6, the experimental group achieved a maximum posttest score of 96 and a minimum score of 8. The mean posttest score was 49.58, with a standard deviation of 23.873 and a variance of 569.934. These results indicate a substantial improvement in students' critical thinking skills following the intervention compared to their pretest performance. Nevertheless, the relatively high standard deviation and variance suggest considerable variability in achievement among students.

In the control group, posttest scores ranged from 10 to 73, with a mean score of 32.64 and a standard deviation of 15.198. The variance was recorded at 230.990. Although the control group also demonstrated improvement in critical thinking performance relative to the pretest results, the increase was less pronounced than that observed in the experimental group. Furthermore, the score distribution reflected a moderate level of variation among students. Descriptive statistics were first used to summarize students' performance. The Shapiro–Wilk test was selected to examine normality because each group contained fewer than 50 participants. Levene's test was conducted to assess homogeneity of variance before

comparing groups. Since the assumptions of normality and homogeneity were satisfied, an Independent Samples t-test was employed to determine whether significant differences existed between the experimental and control groups.

Normality Test

The assumption of normality was evaluated using SPSS version 25, and the outcomes of the analysis are reported in the following table.

Table 7.

Shapiro–Wilk Normality Test Results

		Shapiro-Wilk		
	Class	**Statistic**	**df**	**Sig.**
Pre Test Score	Class Experiment	.935	26	.099
	Class Control	.965	25	.519

The results of the Shapiro–Wilk normality test showed significance values of 0.099 for the experimental group and 0.519 for the control group. As both values exceeded the criterion level of 0.05, the null hypothesis was retained, indicating that the data met the assumption of normality and were derived from normally distributed populations.

Table 8.

Shapiro–Wilk of Normality Test of Post-Test Results

		Shapiro-Wilk		
	Class	**Statistic**	**df**	**Sig.**
Post Test Score	Class Experiment	.952	26	.259
	Class Control	.930	25	.085

Based on the results of the normality test, it shows that the research data is nomally distributed with Sig. > 0.05, namely the experimental class of 0.259> 0.05. The normality analysis revealed a significance value of 0.085 for the control group. As this value exceeded the established alpha level of 0.05, the null hypothesis of normality was retained, confirming that the data were normally distributed.

Homogeneity Test

The homogeneity test was carried out using SPSS version 25 to assess the equality of variances across groups, and the results are presented in the following table.

Table 9.

Levene's Test of Homogeneity of Variance

		Levene Statistic	**df1**	**df2**	**Sig.**
Pre Test Score	Based on Mean	3.609	1	49	.063

The results of Levene's test revealed a significance value of 0.063 for the experimental and control groups. As this value exceeded the established significance criterion ($p > 0.05$), the null hypothesis of equal variances was retained. These findings indicate that the data were derived from populations with homogeneous variances, confirming the homogeneity of the two groups.

Table 10.

Levene's Homogeneity Test of Post-Test Results

		Levene Statistic	df1	df2	Sig.
Post Test Score	Based on Mean	3.459	1	49	.069

The results of Levene's test based on the mean revealed a significance value of 0.069. Because this value was higher than the specified significance level of 0.05, the null hypothesis of homogeneity was retained, indicating that the samples were drawn from populations with equal variances.

Balance Test

A balance test was conducted using SPSS to determine whether the experimental and control groups were comparable prior to the intervention. The results of the analysis are presented in the following table:

Table 11.

Output of Balance Test

		F	Sig.	t	df	Sig. (2-tailed)
Pre Test Score	Equal variances assumed	3.609	.063	2.611	49	.012

Based on the table above, the Sig. (2-tailed) is 0.012, because the value of Sig. < 0.05 then H_0 is accepted, so it can be concluded that the two classes are not equal or not in a balanced state. In educational experimental research, the imbalance between groups is not always made perfectly balanced (Sudartianto et al., 2017). Notwithstanding the unequal sample sizes across the experimental and control groups, the Independent Samples t-test remained an appropriate analytical procedure, given that the assumption of variance homogeneity was satisfied. This is also supported by Delacre et al. (2017) that the Independent Samples t-test can generate accurate and reliable estimates even when group sizes are unequal, provided that the assumption of homogeneity of variance is satisfied. As this assumption was verified in the present study, the use of the Independent Samples t-test was considered statistically appropriate for comparing the experimental and control groups. Therefore, the findings offer robust evidence regarding the effectiveness of the ethnomathematics-based Problem-Based Learning model integrated with the Teaching at

the Right Level approach in improving students' critical thinking skills within authentic classroom settings.

RESULT AND DISCUSSION

Result

Hypothesis Test

Hypotheses are temporary conjectures on questions or problem formulations in research. The results of the preliminary assumption testing confirmed that the data collected from both the experimental and control groups met the requirements of normality and homogeneity. Having satisfied these conditions, the study formulated the following hypotheses for inferential analysis.

H_0 : There is no statistically significant difference in the critical thinking abilities of seventh-grade junior high school students between classes that used an ethnomathematics-based model with a TaRL approach and classes that used a PBL model without involving ethnomathematics and without a TaRL approach.

H_1 : There is statistically significant difference in the critical thinking abilities of seventh-grade junior high school between classes that use the ethnomathematics-based PBL model with the TaRL approach and classes that use the PBL model without involving ethnomathematics and without the TaRL approach.

To evaluate the proposed hypotheses, an Independent Samples t-test was conducted using a 5% significance threshold. The test was applied to examine whether the differences observed between the experimental and control groups were statistically significant. Hypothesis decisions were made based on the two-tailed probability value. A p-value of 0.05 or lower indicated sufficient evidence to reject the null hypothesis in favor of the alternative hypothesis, whereas a p-value greater than 0.05 resulted in the retention of the null hypothesis. The outcomes of the statistical analysis are summarized in Table 12.

The intervention also demonstrated a large practical effect (Cohen's d = 0.84), indicating that the observed difference was not only statistically significant but also educationally meaningful. The results of the Independent Samples t-test indicated a two-tailed significance value of 0.006 Because Levene's test indicated unequal variances (p = .022), the Welch's t-test results (equal variances not assumed) were interpreted. The analysis showed a statistically significant difference between groups, t (43.28) =2.93, p=.005. Given that the obtained p-value was lower than the predetermined alpha level of 0.05, the null hypothesis was rejected in favor of the alternative hypothesis. This finding confirms a statistically significant difference in the critical thinking abilities of seventh-grade students between the experimental group, which received the ethnomathematics-based Problem-

Based Learning model integrated with the Teaching at the Right Level approach, and the control group, which received PBL instruction without ethnomathematical integration or differentiated learning support. The statistical analysis indicates that students who learned through the integrated ethnomathematics-based PBL and TaRL model achieved significantly higher critical thinking performance than those receiving conventional PBL instruction. This finding suggests that the proposed instructional framework was associated with better learning outcomes.

Table 12.

Independent Samples t-Test Results for Students' Critical Thinking Scores

		Levene's Test for Equality of Variances		**t-test for Equality of Means**		
		F	Sig.	t	df	Sig. (2-tailed)
Post Test Score	Equal variances assumed	5.590	.022	2.880	48	.006
	Equal variances not assumed			2.928	43.280	.005

The improvement may be explained by the complementary roles of the three instructional components. Ethnomathematics reduced the abstract nature of mathematics by connecting concepts with familiar cultural experiences. Problem-Based Learning encouraged students to analyze authentic problems collaboratively, while TaRL ensured that learning tasks matched students' readiness levels. Together, these components reduced cognitive barriers and increased opportunities for higher-order reasoning.

The superior performance of the experimental group can be interpreted through the perspective of constructivist learning theory. Constructivism posits that learners actively construct knowledge through meaningful engagement with authentic problems rather than passively receiving information. Within the ethnomathematics-based PBL environment, students were encouraged to investigate culturally contextualized mathematical situations, formulate hypotheses, negotiate meanings with peers, and construct mathematical concepts through collaborative inquiry. Such learning processes promote deeper conceptual understanding and facilitate higher-order cognitive processes required for critical thinking.

From a sociocultural perspective, learning occurs through social interaction and cultural mediation. Ethnomathematics provides cultural artifacts that function as mediational tools, enabling students to connect abstract mathematical concepts with familiar cultural experiences. Collaborative problem solving further supports cognitive development through dialogue and scaffolding, allowing students to internalize more

sophisticated reasoning processes. Situated learning theory further explains these findings by emphasizing that knowledge is constructed within authentic contexts. Embedding mathematics problems into local cultural practices allows students to perceive mathematics as meaningful rather than abstract, thereby increasing engagement and encouraging reflective thinking.

Several instructional mechanisms may explain the superior performance of the experimental group. First, ethnomathematics contextualized mathematical concepts within students' cultural experiences, thereby reducing cognitive abstraction and facilitating conceptual understanding. Second, Problem-Based Learning encouraged students to analyze authentic problems, evaluate alternative strategies, and justify mathematical arguments. Third, the TaRL approach ensured that instructional tasks matched students' readiness levels, preventing cognitive overload among lower-achieving students while maintaining sufficient challenge for higher-achieving students. The interaction among these three instructional components likely created an environment conducive to developing critical thinking skills.

The findings have several practical implications. First, mathematics teachers are encouraged to integrate local cultural contexts into Problem-Based Learning activities to make mathematics more meaningful and relevant. Second, differentiated instruction based on the Teaching at the Right Level approach should be incorporated into daily classroom practice to accommodate students with diverse learning readiness. Third, curriculum developers may consider embedding ethnomathematical contexts and differentiated learning strategies within mathematics curriculum documents. Finally, teacher professional development programs should provide training on designing culturally responsive and differentiated mathematics instruction.

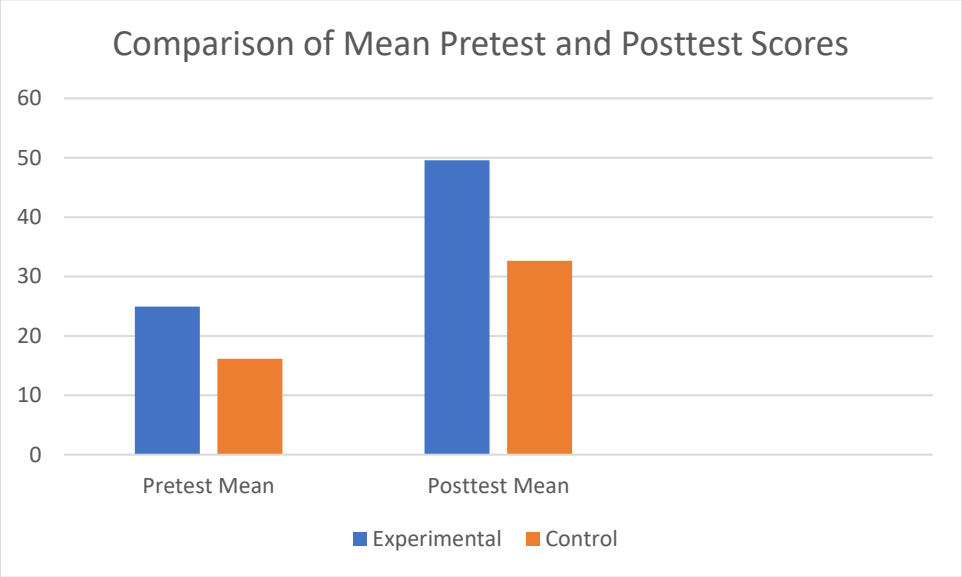
Unlike previous studies that examined ethnomathematics or TaRL separately, the present study empirically demonstrates that integrating contextual learning, inquiry-based learning, and differentiated instruction within a single instructional framework provides complementary support for developing students' critical thinking skills.

Discussion

Following the implementation of the instructional treatments in the experimental and control groups, students’ critical thinking skills were assessed through pretest and posttest instruments covering the topic of quadrilateral perimeter and area, including squares, rectangles, and rhombuses. Before testing the research hypotheses, the collected data were subjected to normality and homogeneity analyses to determine whether the assumptions required for parametric statistical testing had been met. Comparison of Mean Pretest and Posttest Scores are summarized in Figure 1.

Figure 1.

Comparison of Mean Pretest and Posttest Scores



The normality assumption was examined using the Shapiro–Wilk test with the aid of SPSS version 25. The obtained significance values were 0.259 for the experimental group and 0.085 for the control group, both exceeding the criterion value of 0.05. Consequently, the null hypothesis was retained, confirming that the data followed a normal distribution. Following verification of this assumption, a homogeneity analysis was performed to evaluate whether the sample data originated from populations with equal variances.

Levene's test for homogeneity of variance yielded a significance value of 0.069 based on the mean. So, both experimental and control classes have a value of 0.069. Sig. ≥ 0.05 then H_0 is accepted and H_1 is rejected, meaning that the sample comes from a population that has homogeneous variance.

The results of hypothesis testing conducted using the Independent Sample T Test assisted by the SPSS 25 For Windows program with a significance level of 0.05 obtained a result of 0.006. Since the obtained p-value (0.006) was lower than the established significance level of 0.05, the null hypothesis was rejected in favor of the alternative hypothesis. This finding indicates a statistically significant difference in the critical thinking performance of seventh-grade junior high school students between those who participated in the ethnomathematics-based Problem-Based Learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach and those who received PBL instruction without ethnomathematical integration or differentiated learning support. The present findings are consistent with those reported by Hadi Saputro et al. (2020) who demonstrated the effectiveness of an ethnomathematics-based PBL model in enhancing students' mathematical problem-solving abilities. Their study revealed that the integration of ethnomathematical contexts within PBL produced more favorable outcomes than

conventional lecture-oriented instruction. Similarly, the results align with the study conducted by Fatimah et al. (2024) which highlighted the effectiveness of combining the PBL model with the TaRL approach in improving students' mathematical problem-solving performance on matrix-related topics. The study showed that the PBL model with the TaRL approach was more effective on students' mathematical problem solving on matrix material.

The findings of the present study are further supported by the research conducted by Azizah et al. (2019) entitled "Effectiveness of Problem-Based Learning and Guided Inquiry Models on Students' Mathematical Critical Thinking Skills." Their study reported that students who learned through the Problem-Based Learning model achieved a mean critical thinking score of 80.61, which was higher than the mean score of 75.75 obtained by students in the Guided Inquiry group. These results highlight the effectiveness of PBL in fostering mathematical critical thinking abilities.

Additional support for the present findings is provided by the study of Nadziroh et al. (2023). which investigated the integration of the Teaching at the Right Level (TaRL) approach within a Problem-Based Learning framework. Their results demonstrated a continuous improvement in students' critical thinking performance, with achievement levels increasing from 33% to 73% and subsequently reaching 78%. These findings suggest that the incorporation of the TaRL approach into PBL can substantially enhance students' critical thinking skills.

The findings demonstrate a statistically meaningful disparity in critical thinking performance between the experimental and control groups. Students who experienced the ethnomathematics-oriented PBL model supported by the TaRL approach achieved superior outcomes, as evidenced by a higher mean score (M = 49.58) compared with the control group (M = 32.64). The experimental group also achieved a broader score range, with scores varying from 8 to 96, whereas the control group obtained scores ranging from 10 to 73.

The superior performance of the experimental group suggests that the integration of culturally contextualized learning experiences and ability-based instructional strategies can effectively enhance students' critical thinking competencies. Such an approach encourages active participation in problem-solving processes, thereby fostering analytical thinking, conceptual understanding, and independent learning.

Overall, based on the research data, it can be concluded that the ethnomathematics-based PBL model with the TaRL approach is more effective in improving the critical thinking skills of seventh grade students of Junior High School relative to the conventional PBL model without involving ethnomathematics and without the TaRL approach.

This study has several limitations. First, the study involved students from only one junior high school, limiting the generalizability of the findings to other educational contexts. Second, the relatively small sample size may reduce statistical power. Third, students' critical

thinking skills were assessed using only three test items, which may not comprehensively capture the multidimensional nature of critical thinking. Finally, although the study employed a quasi-experimental design, significant differences in pretest scores between groups indicate that baseline equivalence was not fully achieved. Therefore, future studies are encouraged to involve larger samples, multiple schools, more comprehensive assessment instruments, and statistical procedures such as ANCOVA to better control for baseline differences.

Future studies should investigate the long-term effects of the integrated instructional model across different grade levels and mathematical topics. Further research may also examine its influence on other higher-order thinking skills, including computational thinking, creativity, and mathematical reasoning. Conceptually, this study proposes that the integration of contextual learning (ethnomathematics), inquiry-based learning (Problem-Based Learning), and differentiated instruction (TaRL) forms a complementary instructional framework capable of supporting higher-order cognitive development.

CONCLUSION

This study suggests that integrating ethnomathematics and the Teaching at the Right Level (TaRL) approach within a Problem-Based Learning (PBL) framework is associated with higher critical thinking performance among junior high school students compared with conventional PBL instruction. The findings indicate that combining culturally contextualized learning, inquiry-based problem solving, and differentiated instruction provides a complementary instructional framework that supports students' higher-order thinking development.The primary contribution of this study lies in providing empirical evidence for the integrated implementation of ethnomathematics, PBL, and TaRL within a single instructional model. While previous studies have generally examined these approaches separately or in partial combinations, this study demonstrates that their integration offers complementary pedagogical benefits for fostering meaningful, culturally responsive, and differentiated mathematics learning. These findings extend the existing literature on mathematics education by highlighting the importance of simultaneously addressing contextual relevance and students' diverse learning readiness. From a practical perspective, the findings suggest that mathematics teachers may enhance classroom learning by incorporating local cultural contexts into problem-based activities while differentiating instructional support according to students' readiness levels. Curriculum developers and teacher education institutions may also consider integrating these principles into curriculum design, instructional materials, and professional development programs to better accommodate learner diversity.

This study has several limitations. The research was conducted in a single junior high school with a relatively small sample, and students' critical thinking was assessed using a limited number of test items. In addition, the quasi-experimental design and the initial differences between the experimental and control groups warrant cautious interpretation of the findings and limit the generalizability of the results. Future research is encouraged to involve larger and more diverse samples across multiple schools, examine the long-term effects of the integrated instructional model through longitudinal studies, investigate its implementation across different mathematical topics and educational levels, and employ more rigorous analytical approaches, such as ANCOVA or randomized experimental designs, together with more comprehensive critical thinking assessments. Overall, the proposed instructional framework represents a promising direction for advancing equitable, culturally responsive, and differentiated mathematics education.

DECLARATIONS

Author Contribution

Taufik, I., Conceptualization, Investigation, Resources, and Writing - original draft; **Abadi, A.M.,** Validation, research supervision, and critical revision of the manuscript for intellectual content; **Wijaya,A.,** Validation, research supervision, and critical revision of the manuscript for intellectual content; **Istiqomah.,** Editing and Visualization, Formal analysis, and Methodology; **Utami, N.R.,** Writing, teaching, and data analysis.

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The authors declare no conflict of interest.

Declaration of AI Use

No generative AI tools were used in the preparation of this manuscript.

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