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Mathematical Process Skills of Middle School Students under Direct Instruction and Ethnomathematics

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ABSTRACT

Mathematics instruction at the junior high school level in Indonesia is often teacher-centred, which may limit the development of students' mathematical process skills. This study investigates the impact of Direct Instruction and ethnomathematics-based Problem-Based Learning (PBL) on the mathematical process skills of seventh-grade students. A quantitative quasi-experimental design with a nonequivalent control group was employed, involving 64 students at SMP Negeri 7 Kota Jambi, divided into an experimental and a control group. Data were collected through pretests and posttests assessing skills such as observing, classifying, identifying relationships, calculating, and communicating mathematical ideas. Data analysis included descriptive statistics and the Mann-Whitney U test. The results revealed that students receiving ethnomathematics-based PBL exhibited greater improvement in mathematical process skills than their peers taught via Direct Instruction, indicating that integrating local cultural contexts within a PBL framework can enhance mathematical reasoning, problem-solving, and active engagement in learning.

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1. INTRODUCTION

Mathematics is a fundamental subject essential for fostering students' analytical and advanced thinking skills. Etymologically, the term mathematics originates from the Latin words *manthanein* or *mathema*, which denote learning and acquired knowledge. The Great Indonesian Dictionary defines mathematics as a scientific field concerned with numbers, numerical relationships, and operational procedures used in problem solving [1]. In accordance with this definition, mathematics education should not merely emphasise procedural proficiency but should also foster students' logical reasoning, analytical capacity, and critical judgment. From a theoretical standpoint, meaningful mathematics learning

occurs when abstract concepts are connected to students' real-life experiences, thereby facilitating active cognitive engagement [2].

Despite these expectations, mathematics instruction at the middle school level remains predominantly teacher-centred. Classroom activities are generally dominated by lectures, demonstrations, and repetitive exercises, which restrict students' opportunities to think critically, explore concepts, and independently analyse problems [3]. This condition is further intensified by the abstract nature of mathematical content, particularly when instruction is not supported by contextual or experiential learning. Consequently, many students struggle to develop conceptual understanding and apply mathematical knowledge meaningfully in real-world situations. This discrepancy between theoretical ideals and instructional practice indicates a pedagogical problem that requires systematic improvement.

Students' achievement in mathematics is closely associated with their mathematical process skills. Mathematical process skills refer to a set of cognitive and creative abilities developed through learning activities to support effective problem solving and meaningful learning outcomes [4]. These skills include identifying and interpreting problems, organising and processing information, exploring mathematical ideas, **applying appropriate problem-solving strategies, communicating mathematical reasoning**, and making independent decisions [5], [6]. Theoretically, mathematical process skills constitute a fundamental component of mathematics education, as they enable students to construct knowledge rather than passively receive information.

International assessment findings reinforce the urgency of enhancing students' mathematical process skills. The 2022 Programme for International Student Assessment (PISA) data indicate that Indonesian students' mathematics achievement continues to fall below the OECD average, with only about 18% reaching Level 2 or higher [7]. Most students struggle to apply mathematical concepts to solve basic contextual problems, while only a limited proportion demonstrate advanced reasoning skills. These results suggest that students' abilities to process, apply, and interpret mathematical concepts remain inadequate, underscoring the need for instructional approaches that explicitly emphasise the development of mathematical process skills.

Instructional models play a critical role in addressing these challenges. Direct instruction is a structured, teacher-centred approach that prioritises systematic explanation, guided practice, and continuous feedback. Previous studies have demonstrated that Direct Instruction effectively improves students' learning outcomes and conceptual understanding in mathematics [8], [9]. However, this approach is often criticised for providing limited opportunities for student exploration, inquiry, and independent problem-solving, which are essential for developing mathematical process skills.

In contrast, ethnomathematics-based learning adopts a contextual approach by integrating elements of local culture into mathematics instruction. This approach enables students to relate mathematical concepts to familiar cultural practices, thereby enhancing the relevance and concreteness of learning experiences [10]–[12]. Empirical evidence indicates that ethnomathematics-based learning increases student engagement, reduces perceptions of mathematics as an abstract subject, and improves conceptual understanding while fostering cultural appreciation [13]. Its effectiveness tends to be enhanced when implemented through

a Problem-Based Learning (PBL) framework, which emphasises contextual problems, collaborative inquiry, and active knowledge construction. Several studies have reported that ethnomathematics-based PBL can substantially enhance students' capacities in **critical thinking and problem-solving**, which are **essential components of** mathematical process skills [14], [15].

A number of prior studies have examined the effectiveness of Direct Instruction and ethnomathematics-based approaches in mathematics education. Hanum et al. (2023) found that Direct Instruction positively influences students' conceptual understanding, serving as a foundation for mathematical learning, although it tends to limit opportunities for independent exploration [16]. Conversely, Syahniah et al. (2024) found that Problem-Based Learning incorporating ethnomathematics notably enhances students' capacities for critical thinking [2]. **Studies conducted by** Ardiana et al. (2025) **and** Septiani et al. (2023) revealed that students who received instruction through **ethnomathematics-based Problem-Based Learning** demonstrated superior **mathematical problem-solving** performance compared to those taught via Direct Instruction [17], [18]. Similarly, Kamid et al. (2023) demonstrated that ethnomathematics-based learning enables students to consistently exhibit multiple indicators of mathematical process skills during problem-solving activities [3].

Nevertheless, most existing studies have focused on specific mathematical abilities, such as problem solving or critical thinking, rather than examining mathematical process skills as a holistic construct. Moreover, empirical studies that directly compare middle school students' mathematical process skills between Direct Instruction and ethnomathematics-based Problem-Based Learning remain limited, particularly within the context of local culture in Jambi. This research gap is further reinforced by classroom observations and interviews with mathematics teachers at SMP Negeri 7 Kota Jambi, which indicate that mathematics instruction is still largely dominated by lectures and routine exercises. Although the potential of ethnomathematics to enhance students' mathematical process skills is widely acknowledged, its implementation remains constrained by limited instructional time, insufficient resources, and teachers' pedagogical experience.

In light of these considerations, the present study seeks to examine the mathematical process skills of middle school students receiving instruction through Direct Instruction compared with those receiving instruction through ethnomathematics-based Problem-Based Learning. The results are anticipated to offer empirical **insights into the relative effectiveness of these instructional methods and to** inform **the** design of more effective, contextually relevant, and meaningful mathematics learning practices that enhance students' mathematical process skills.

2. METHOD

This research employs **a quantitative approach** utilising **a quasi-experimental design**. Specifically, a **Nonequivalent Control Group Design** was implemented, involving two class groups with no random assignment of participants. This design was employed because the researcher faced constraints in performing randomisation; nevertheless, it permits the evaluation of the treatment's effect on the dependent variable through pretest and posttest measurements [19].

This research was carried out at SMP Negeri 7 Kota Jambi during the first semester of the 2025/2026 academic year. The research participants comprised 64 seventh-grade students, divided into two groups: 32 students in the experimental class and 32 students in the control class. The experimental group received instruction through ethnomathematics-based Problem-Based Learning (PBL), whereas the control group received instruction through Direct Instruction. The research design is illustrated in Table 1.

Table 1. Nonequivalent Control Group Design

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

Description:

- X_1 : The treatment consisted of ethnomathematics learning combined with the Problem-Based Learning (PBL) model.
- X_2 : The treatment consisted of learning using a Direct Instruction approach.
- O_1 : The scores obtained by students on the pretest were used to assess their initial abilities before treatment.
- O_2 : The posttest scores obtained by students were used to assess their mathematical process skills after the treatment was applied.

The study population included all seventh-grade students at SMP Negeri 7 Kota Jambi. Purposive sampling was employed, taking into account the equivalence of initial abilities, the consistency of the curriculum, and the similarity of learning conditions across classes [19].

Data collection was conducted through written tests, including pretests and posttests. Pretests were administered prior to the treatment to evaluate students' baseline abilities related to the material to be taught, while posttests were administered following the treatment to assess students' mathematical process skills [20]. The mathematical process skills indicators measured include observing, classifying, finding relationships, calculating, and communicating results [21].

Instrument validation was conducted through content validity, involving expert validators to ensure consistency among indicators, learning materials, and test items [19]. Student answers are assessed using a rubric with indicators of mathematical process skills, each scored 0–2, to ensure the assessment is objective and measurable [22], [23].

Data analysis was conducted using descriptive and inferential methods. Descriptive statistics were used to summarise data characteristics, including minimum, maximum, mean, standard deviation, and range. Normality testing was performed using the Kolmogorov–Smirnov test at the 0.05 significance level. The criteria were: if the p – value > 0.05, the data were considered normally distributed; if the p – value \leq 0.05, the data were regarded as not normally distributed [24]. The normality test results indicated that the data did not fully meet normality assumptions. Consequently, hypothesis testing was performed using the Mann–Whitney U nonparametric test. The decision rules were as

follows: if the $p - \text{value} \leq 0.05$, H_0 is rejected, signifying a significant difference between the two groups; if the $p - \text{value} > 0.05$, H_0 is accepted, indicating no significant difference [25]. All computations and analyses were conducted using SPSS version 29.0.

3. RESULTS

3.1. Descriptive Statistics of Mathematical Process Skills

A descriptive analysis of the data was performed to summarise students' mathematical process skills before and after the treatment in the experimental group (ethnomathematics-based learning) and the control group (Direct Instruction). The outcomes of the descriptive analysis are presented in Table 2.

Table 2. Statistical Summary of Students' Mathematical Process Skills

	Descriptive Statistics					
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Pretest	64	38	2	40	25,47	10,268
Posttest	64	72	22	94	64,59	20,793
Valid N (listwise)	64					

According to the descriptive analysis presented in Table 2, the pretest scores ranged from 2 to 40, with a minimum of 2 and a maximum of 40. The mean pretest score was 25.47 with a standard deviation of 10.268. These data suggest that students' mathematical process skills prior to the treatment remained relatively low and showed considerable variation.

Following the learning intervention, the posttest results showed a marked improvement. The minimum posttest score was 22, the maximum was 94, and the range was 72. The mean posttest score increased to 64.59 with a standard deviation of 20.793. The growth in both the mean score and the score range reflects students' development of mathematical process skills through the instructional process.

3.2. Normality Test

Before performing the difference test, a normality assessment was conducted to verify whether the data distribution satisfied the normality assumption. The normality assessment was carried out using the Kolmogorov–Smirnov test, with the criteria that if $\text{Sig.}(p - \text{value}) > 0.05$, the data were considered normally distributed; whereas if $\text{Sig.}(p - \text{value}) \leq 0.05$, the data were considered non-normally distributed. The outcomes of the normality assessment are presented in Table 3.

According to the Kolmogorov–Smirnov test, the p -values for the pretest and posttest data in both the experimental and control groups were below 0.05, indicating that the data did not follow a normal distribution. To validate these findings, a Shapiro–Wilk test was also conducted, which similarly showed significance values of $\text{Sig.} < 0.05$ in most data sets. Therefore, it can be concluded that the data on mathematical process skills violated the normality assumption. Consequently, the Mann–Whitney U Test, a nonparametric method, was employed for the difference analysis.

Table 3. Assessment of Normality for Students' Mathematical Process Skills Data

		Tests of Normality					
		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	Eksperimen	,340	32	<,001	,591	32	<,001
	Control	,243	32	<,001	,863	32	<,001
Post Test	Eksperimen	,200	32	,002	,857	32	<,001
	Control	,102	32	,200*	,969	32	,480

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

3.3 Differences in Mathematical Process Skills Based on Mann–Whitney U Test

The mean ranks for the pretest and posttest assessments of mathematical process skills are shown in Table 4.

Table 4. Mean Rank of Students' Mathematical Process Skills

		Ranks		
	Class	N	Mean Rank	Sum of Ranks
Pretest	Experiment	32	36,13	1156,00
	Control	32	28,88	924,00
	Total	64		
Posttest	Experiment	32	40,02	1280,50
	Control	32	24,98	799,50
	Total	64		

Based on Table 4, during the pretest stage, the mean ranks of both classes were similar, suggesting that students' initial competencies were comparable. After the treatment, the mean rank of the experimental class exceeded that of the control class, demonstrating a positive effect of integrating ethnomathematics learning with Problem-Based Learning on students' mathematical process skills.

The findings of the comparative analysis on mathematical process skills for the experimental and control groups are shown in Table 5.

Table 5. Mann–Whitney U Test on Differences in Mathematical Process Skills

	Pretest	Posttest
Mann-Whitney U	396,000	271,500
Wilcoxon W	924,000	799,500
Z	-1,611	-3,232
Asymp. Sig. (2-tailed)	,107	,001

a. Grouping Variable: Class

According to the Mann–Whitney U test results displayed in Table 5, the testing criteria used are that if the significance value $p > 0.05$, then there is no significant difference between groups; conversely, if the Sig. 2 – tailed value < 0.05 , then there is a significant difference between groups [25]. The Mann–Whitney U test results on the pretest data showed a significance value of $0.107 > 0.05$, so it can be concluded that there was no significant difference between the mathematical process skills of the experimental class and

the control class before the treatment. This shows that the initial abilities of both classes were relatively equal.

Conversely, the Mann–Whitney U test results for the posttest data showed a significance value of $0.001 < 0.05$, which means that there was a significant difference between the mathematical process skills of students taught using ethnomathematics and students taught using direct instruction. These results indicate that ethnomathematics-based learning integrated with the Problem-Based Learning model is more effective than Direct Instruction in enhancing students' mathematical process skills.

4. DISCUSSION

The results reveal that prior to the implementation of the learning treatment, the mathematical process skills of students in the experimental and control classes were largely similar. These results are confirmed by the Mann–Whitney U test results on the pretest data, which showed no statistically significant difference between the two groups (p – value > 0.05). This finding confirms that students' initial abilities were comparable, thereby providing a valid basis for attributing differences observed at the posttest stage to the instructional approaches applied rather than to pre-existing disparities in students' mathematical process skills.

Following the implementation of the learning treatment, the posttest results revealed a statistically significant difference between the experimental and control classes (p – value < 0.05). The experimental class, which implemented ethnomathematics-based learning integrated with the Problem-Based Learning (PBL) model, obtained a higher mean rank than the control class taught using Direct Instruction. This finding suggests that, within the context of this study, ethnomathematics-based PBL provides more favourable conditions for the development of students' mathematical process skills than Direct Instruction.

The present findings align with those of Asmara and Septiana (2023), who found that students receiving PBL integrated with ethnomathematics exhibited higher mathematical problem-solving abilities than their peers taught via Direct Instruction. A similar conclusion was reported by Ardiana and Lu (2025), who found that integrating ethnomathematics into the PBL framework led to superior problem-solving performance among middle school students. Given that problem-solving constitutes a core component of mathematical process skills, the results of the present study reinforce previous findings that ethnomathematics-based PBL supports the development of students' mathematical processes more effectively than teacher-centred instructional approaches.

The improvement in mathematical process skills observed in the experimental class may be explained by the characteristics of ethnomathematics-based PBL, which emphasises active student engagement in observing, interpreting, and solving contextual mathematical problems grounded in local cultural contexts. Through these learning activities, students are encouraged to construct mathematical knowledge rather than merely receive information actively. The present finding aligns with the qualitative research conducted by Kamid et al. (2023), which showed that students engaged in ethnomathematics-based learning displayed multiple indicators of mathematical process skills during problem-solving, despite variations in their comprehension rates. In the present study, the variation in posttest scores within the

experimental class similarly indicates differences in students' levels of mastery, suggesting that ethnomathematics-based PBL provides opportunities for students to engage with mathematical tasks at varying levels of understanding.

Furthermore, the development of mathematical process skills in the experimental class is closely related to the engagement of higher-order thinking processes during learning activities. Syahniah et al. (2024) reported that ethnomathematics-based PBL significantly enhances students' critical thinking skills. In line with this finding, the learning activities implemented in this study—such as analysing contextual problems, formulating solution strategies, and communicating mathematical reasoning—are associated with the development of mathematical process skills, which align conceptually with higher-order thinking abilities.

Conversely, although students in the control class receiving Direct Instruction showed progress in learning outcomes, the degree of improvement was less pronounced than in the experimental class. This finding indicates that Direct Instruction tends to be more effective in supporting students' conceptual understanding than in developing mathematical process skills. The present result aligns with the findings of Hanum et al. (2023), who reported that Direct Instruction has a significant positive effect on students' conceptual understanding of mathematics. Nevertheless, because the development of mathematical process skills requires exploration, reflection, and active student participation, teacher-centred approaches such as Direct Instruction may offer fewer opportunities for students to develop these skills optimally.

Overall, the findings of this study indicate that the observed differences in students' mathematical process skills between the experimental and control classes are closely related to the instructional approaches applied. Ethnomathematics-based PBL offers a contextual, participatory, and meaningful learning environment that supports the development of students' mathematical process skills more favourably than Direct Instruction within the scope of this research.

5. CONCLUSION

This study indicates that ethnomathematics-based Problem-Based Learning provides a more meaningful and effective approach to enhancing junior high school students' mathematical process skills compared to conventional Direct Instruction. By integrating local cultural contexts into mathematics learning, students are encouraged to think critically, solve problems creatively, and engage actively in the learning process, which strengthens their overall understanding and application of mathematical concepts.

Despite the study's limitation to a single school and a relatively small sample, which may affect the generalizability of the results, the findings offer practical insights for educators, curriculum developers, and policymakers seeking to design culturally relevant and student-centred mathematics learning experiences. Future research is recommended to explore the implementation of ethnomathematics-based learning across diverse schools, grade levels, and mathematical topics, and its potential effects on complementary skills such as creativity, collaboration, and long-term retention, thereby contributing to broader

knowledge of effective strategies for fostering higher-order thinking skills in mathematics education.

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