



EFFECTIVENESS OF PROBLEM-BASED LEARNING ON EIGHTH-GRADERS' MATHEMATICAL REASONING IN NUMBER PATTERNS

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ABSTRACT

Mathematical reasoning underlies many higher-order mathematical competencies, yet students' reasoning ability remains a persistent concern, including among eighth-grade students at MTsN 1 Polewali Mandar. This study examined the effectiveness of the Problem-Based Learning (PBL) model in improving students' mathematical reasoning ability in number patterns and sequences. The study used a quantitative quasi-experimental pretest-posttest control group design. Two eighth-grade classes were selected through cluster random sampling and then randomly assigned to the experimental and control conditions (PBL, $n = 40$; conventional instruction, $n = 40$). Mathematical reasoning ability was measured using a five-item essay test that demonstrated satisfactory validity (Pearson item-total correlations ranging from 0.754 to 0.934, $p < 0.01$) and reliability (Cronbach's $\alpha = 0.893$). The data were analyzed using an independent-samples t -test and ANCOVA, with pretest score as a covariate, after the assumptions of normality, homogeneity of variance, and homogeneity of regression slopes were met. The PBL group achieved a significantly higher mean posttest score ($M = 78.75$; $SD = 4.21$) than the control group ($M = 67.40$; $SD = 4.67$), $t(78) = -11.412$, $p < 0.001$, Cohen's $d = 2.55$. After controlling for pretest scores, the difference remained statistically significant, $F(1, 77) = 93.540$, $p < 0.001$, partial $\eta^2 = 0.549$. The overall ANCOVA model explained 72.5% of the variance in posttest scores ($R^2 = 0.725$). Within the context of this sample, PBL was effective in improving students' mathematical reasoning ability.

Keywords: Problem-Based Learning, Mathematical Reasoning Ability, Number Patterns and Sequences

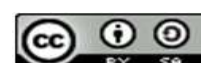
ABSTRAK

Kemampuan penalaran matematis merupakan dasar bagi hampir seluruh kompetensi matematis tingkat tinggi, namun penalaran siswa kelas VIII MTsN 1 Polewali Mandar, Sulawesi Barat, pada materi pola bilangan dan barisan bilangan masih lemah. Penelitian ini bertujuan menguji keefektifan model Problem-Based Learning (PBL) terhadap kemampuan penalaran matematis siswa pada materi tersebut. Desain penelitian adalah kuasi-eksperimen tipe Pretest-Posttest Control Group Design. Dua kelas VIII dipilih melalui cluster random sampling, kemudian diundi untuk menentukan kelas eksperimen (PBL, $n = 40$) dan kelas kontrol (pembelajaran konvensional, $n = 40$). Instrumen tes uraian lima butir terbukti valid (r item-total 0,754-0,934; $p < 0,01$) dan reliabel (α Cronbach = 0,893). Data dianalisis dengan uji- t sampel independen dan ANCOVA dengan skor pretest sebagai kovariat, setelah uji normalitas, homogenitas varians, dan homogenitas kemiringan regresi terpenuhi. Rerata posttest kelas PBL ($M = 78,75$; $SD = 4,21$) lebih tinggi daripada kelas konvensional ($M = 67,40$; $SD = 4,67$), $t(78) = -11,412$; $p < 0,001$; d Cohen = 2,55. Setelah pretest dikontrol, pengaruh model pembelajaran tetap signifikan, $F(1,77) = 93,540$; $p < 0,001$; η^2 parsial = 0,549, sedangkan keseluruhan model ANCOVA menjelaskan 72,5% varians posttest ($R^2 = 0,725$). Dalam konteks sampel ini, PBL efektif mengembangkan penalaran matematis siswa.

Kata Kunci: Problem-Based Learning, Kemampuan Penalaran Matematis, Pola Bilangan dan Barisan Bilangan

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I. INTRODUCTION

Learning mathematics is inseparable from the development of logical, systematic, critical, and creative thought-competencies that mathematics as a discipline is uniquely positioned to cultivate (NCTM, 2000). Within this broader set of thinking skills, reasoning stands out as particularly central: it is what allows a student to propose a conjecture, build a proof, justify why a statement is true, and judge whether an argument actually holds (NCTM, 2000). Without this capacity, students are left able to follow procedures but unable to genuinely understand mathematical ideas or transfer them to situations, whether inside mathematics itself or in everyday problem-solving.

The concern is not merely theoretical. Domestic and international assessments repeatedly flag Indonesian students' reasoning skills as underdeveloped. Results from the Trends in International Mathematics and Science Study, for instance, put Indonesian students' accuracy on reasoning-type items at roughly 20 percent, less than half the international average of 44 percent (Darwani et al., 2020). Number patterns appear to be an especially common trouble spot, because students frequently misidentify the underlying regularity, fail to state a valid generalization, or cannot construct an argument that proves their claim (Suhartatik et al., 2023; Utomo et al., 2022). Learning style and other individual characteristics further differentiate which reasoning indicators students are able to reach (Fauziah & Kusnandi, 2025).

The same weakness was documented locally. A preliminary study was carried out at MTsN 1 Polewali Mandar in April 2026, in which a diagnostic test consisting of five reasoning items on number patterns and sequences was administered to 80 eighth-grade students who had already studied the topic. The class mean was only 66.18 out of 100, below the school's minimum mastery criterion of 70, and 75.32% of the students scored under that criterion. Item-level analysis was more specific: 72% of the students were unable to formulate a general rule for a given pattern, and 65% gave a final answer without any supporting justification. Classroom observation across two lessons in the same period showed a matching pattern, with student work dominated by formula substitution rather than by explanation. Taken together, these preliminary findings indicate that the difficulty at this school is concentrated precisely in the reasoning-heavy aspects of the topic.

Part of the explanation may lie in how the topic is typically taught. Instruction that remains teacher-centered tends to train students to reproduce formulas and steps rather than to understand the reasoning that produced them (Ikasari & Firmansyah, 2023). When students are rarely asked to grapple with a genuine problem on their own, models of this kind do little to build higher-order skills such as reasoning (Kurniyawati et al., 2019). What this points to is the need for an instructional approach that pushes students to investigate, analyze, and argue for themselves, rather than absorb a solution procedure passively.

Problem-Based Learning (PBL) is one such approach: it opens instruction with an authentic, contextual problem rather than with content delivery, and moves students through a defined sequence orienting them to the problem, organizing them for learning, guiding individual and group investigation, supporting the development and presentation of solutions, and finally analyzing and evaluating the process used to reach them (Arends, 2008). Because that sequence requires students to identify what the problem actually is, gather relevant information, propose conjectures, and reach conclusions in a structured way, PBL has been proposed as a model well-suited to strengthening mathematical reasoning specifically (Abidah et al., 2021; Afifah et al., 2018). Empirical support for this claim already exists across several mathematical topics, including social arithmetic (Abidah et al., 2021) and circle geometry, with or without GeoGebra support (Dewi & Saragih, 2023; Sugandi et al., 2020). Across these studies, the pattern is consistent: PBL outperforms conventional instruction when the outcome of interest is mathematical reasoning.

Two gaps remain in this body of work. First, the evidence for PBL and mathematical reasoning has been gathered mainly on topics such as social arithmetic, circles, and general problem solving, whereas number patterns and sequences have been studied largely in descriptive terms, that is, as a source of diagnosed student errors rather than as the setting for a controlled test of a learning model (Suhartatik et al., 2023; Utomo et al., 2022). Second, most of the experimental evidence comes from SMP or SMA settings, so it is not yet clear whether the same advantage appears at the Madrasah Tsanawiyah level, where mathematics instruction is delivered within an integrated religious and general curriculum and lesson time for mathematics is comparatively limited. The topic itself makes this gap worth closing, since number patterns and sequences require students to notice regularities, translate them into a general statement, and defend that statement's validity, which is mathematical reasoning in a concentrated form (Maryati, 2018). The present study therefore tests the effectiveness of PBL in improving mathematical reasoning ability in number patterns and sequences at the Madrasah Tsanawiyah level.

Building on this rationale, the present study examines how effective the PBL model is at improving mathematical reasoning ability among eighth-grade students at MTsN 1 Polewali Mandar on the topic of number patterns and sequences. Two objectives follow from this aim: first, to compare the reasoning ability of students taught through PBL with that of students taught conventionally; and second, to determine whether a difference between the two groups persists once prior ability (pretest score) is statistically controlled. The hypothesis tested is that mathematical reasoning ability differs significantly between students who receive PBL instruction and those who receive conventional instruction on this topic.

II. METHOD

The study used a quantitative, quasi-experimental design, specifically a Pretest-Posttest Control Group Design. A quasi-experimental rather than a fully experimental design was necessary because the field setting did not permit random assignment of individual students; existing, naturally formed classes had to be used as the units of comparison. What could be randomized — and was — was which of the available eighth-grade classes would serve as the experimental group and which as the control group (Sugiyono, 2014). Table 1 summarizes this design.

Table 1. Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O1	X	O2
Control	O1	-	O2

Source: Adapted from Sugiyono, **Year:** 2014

The research was conducted at MTsN 1 Polewali Mandar, West Sulawesi Province, during the second semester of the 2025/2026 academic year. The population comprised all eighth-grade students at the school, that is, 287 students distributed across 8 parallel classes. Sampling proceeded in two stages. First, cluster random sampling was applied: all eighth-grade classes taught by the same mathematics teacher and following the same syllabus were eligible, and two classes were drawn by lottery so that selection did not depend on the researcher's judgment or on class achievement rankings. Their comparability was then checked against the previous semester's mathematics report scores, which showed means of 73.5 and 74, with a difference of only 0.5 points between the two classes. Second, the status of each drawn class was decided by a further lottery, which assigned class 8G to the experimental group ($n = 40$) and class 8F to the control group ($n = 40$), giving a combined sample of 80 students.

The experimental group was taught with the PBL model through its five phases, namely orienting students to the problem, organizing them for learning, guiding investigation, developing and presenting the solution, and analyzing and evaluating the problem-solving process (Arends, 2008). The control group was taught conventionally, that is, through expository instruction in which the teacher explained the concept and worked through examples, students recorded the procedure and practiced similar exercises individually, and the lesson closed with teacher-led correction of the answers. Both groups were taught by the same teacher, covered the same content on number patterns and sequences and the same learning objectives, and received the same allocation of time: four meetings of 2×40 minutes each, spread over three weeks, excluding the pretest and posttest sessions. The only systematic difference between the groups was the learning model. Fidelity of implementation was monitored with a PBL implementation observation sheet completed by the

partner teacher at every meeting in the experimental class, yielding an average implementation of 87.5%.

Mathematical reasoning ability was measured with an essay-format instrument on number patterns and sequences, built around five recognized reasoning indicators: formulating conjectures, carrying out mathematical manipulation, constructing proofs or otherwise justifying the correctness of a solution, drawing conclusions from a given statement, and evaluating the validity of an argument (NCTM, 2000). The instrument consisted of five items, one for each indicator, and was scored with an analytic rubric ranging from 0 to 4 per item; the total raw score was then converted to a 0-100 scale. Because all responses were scored by a single researcher using the same mathematical-reasoning rubric, inter-rater reliability was not assessed. Before being used with the study sample, the instrument was trialed on 30 students outside the sample who had already studied the topic. Item validity was established through Pearson item-total correlations and reliability through Cronbach's alpha, both computed in SPSS.

The pretest was administered to both groups in the same week, on April 13, 2026, before any treatment began, and the posttest on April 30, 2026, in the week following the final treatment meeting. Both tests were administered in the students' own classrooms under the supervision of the researcher and the subject teacher, lasted 80 minutes, and used parallel forms of equivalent difficulty covering the same five indicators, so that the posttest did not simply repeat the pretest items.

Alongside the tests, student learning activity was recorded with a structured classroom observation sheet in order to describe the learning process rather than to test a hypothesis. The sheet covered four indicators of student activity, each rated on a 1-4 scale. It was completed by the partner mathematics teacher (guru mitra) in both the experimental and control classes at every meeting, and the results were summarized descriptively as percentages. These observation data are reported in the discussion only as supporting information and are not used as evidence of the treatment effect.

Data analysis proceeded in three steps. First, the prerequisite assumptions were tested: normality with the Shapiro-Wilk test, chosen because each group contained fewer than 50 cases; homogeneity of variance with Levene's test; and homogeneity of regression slopes through the interaction between the covariate and the group factor in a preliminary general linear model, which is a specific requirement of ANCOVA. Second, the hypothesis was tested with an independent-samples t-test comparing posttest means. Third, an ANCOVA was run with pretest score as covariate so that the effect of the instructional model on posttest performance could be examined independently of any pre-existing difference in ability. Effect sizes were reported alongside every significance test, namely Cohen's d for the t-test and partial eta squared for the ANCOVA, and were interpreted using conventional benchmarks (Fritz et al., 2012).

All analyses were conducted in SPSS at a significance level of 0.05, testing the following hypotheses:

- H_0 : There is no difference in mathematical reasoning ability between students taught with the Problem-Based Learning model and students taught conventionally.
- H_1 : There is a difference in mathematical reasoning ability between students taught with the Problem-Based Learning model and students taught conventionally.

III. RESULTS AND DISCUSSION

A. Results

1. Instrument Validity and Reliability Test Results

The 30-student pilot confirmed that every item on the reasoning test was valid, with item-total Pearson correlations ranging from 0.754 to 0.934, all significant at $p < 0.01$ (table 2). Cronbach's alpha across the five items reached 0.893, comfortably within the range considered indicative of strong internal consistency, confirming that the instrument was suitable for measuring reasoning ability in this study.

Table 2. Item Validity Test Results (Item-Total Correlation)

Item	Correlation Coefficient (r)	Sig. (2-tailed)	N	Description
Item 1	0.920	0.000	30	Valid
Item 2	0.833	0.000	30	Valid
Item 3	0.934	0.000	30	Valid
Item 4	0.754	0.000	30	Valid
Item 5	0.782	0.000	30	Valid

Source: SPSS Output, **Year:** 2026

2. Prerequisite Test Results

Before hypothesis testing, the pretest and posttest scores of both groups were checked against the assumptions required for parametric analysis. Table 3 reports the Shapiro-Wilk results.

Table 3. Shapiro-Wilk Normality Test Results

Data	Group	Statistic	df	Sig.
Pretest	Control	0.978	40	0.604
Pretest	Experimental	0.979	40	0.637
Posttest	Control	0.968	40	0.322
Posttest	Experimental	0.963	40	0.213

Source: SPSS Output, **Year:** 2026

Every significance value in table 3 sits well above the 0.05 threshold, meaning normality can be assumed for both the pretest and posttest data in each group. Homogeneity of variance was checked next, using Levene's test on the posttest scores (table 4).

Table 4. Levene's Test of Homogeneity of Variance for Posttest Data

Data	Levene Statistic	df1	df2	Sig.
Posttest (Based on Mean)	0.155	1	78	0.695

Source: SPSS Output, **Year:** 2026

Because Levene's test was non-significant ($p = 0.695$), the assumption of homogeneity of variance was satisfied. Because both prerequisite assumptions were satisfied, the independent-samples t-test and ANCOVA could proceed as planned.

3. Descriptive Data and Hypothesis Testing

Table 5. Descriptive Statistics of Posttest Scores

Group	N	Mean	Std. Deviation	Std. Error Mean
Control	40	67.40	4.673	0.739
Experimental	40	78.75	4.211	0.666

Source: SPSS Output, **Year:** 2026

Table 5 shows a gap of 11.35 points favoring the experimental group ($M = 78.75$ vs. $M = 67.40$ for the control group). Whether that gap was statistically meaningful was tested next with an independent-samples t-test (table 6).

Table 6. Independent Samples t-Test Results for Posttest Scores

t	df	Sig. (2-tailed)	Mean Difference	95% CI Lower	95% CI Upper
-11.412	78	0.000	-11.350	-13.330	-9.370

Source: SPSS Output, **Year:** 2026

With $t(78) = -11.412$ and $p < 0.001$, H_0 was rejected in favor of H_1 , indicating a statistically significant difference in mathematical reasoning ability between students taught with PBL and those taught conventionally. A supplementary one-way ANOVA on the same posttest data reached the same conclusion ($F = 130.233$, $p < 0.001$)-unsurprising given that F is mathematically equivalent to t^2 in this two-group case, but useful as a cross-check. Because the two groups might simply have differed in starting ability, an ANCOVA was run with pretest score entered as covariate (table 7).

Table 7. Analysis of Covariance (ANCOVA) Results-Dependent Variable: Posttest

Source	Type III SS	df	Mean Square	F	Sig.
Corrected Model	2984.868	2	1492.434	101.277	0.000
Pretest (Covariate)	408.418	1	408.418	27.715	0.000
Group (Learning Model)	1378.411	1	1378.411	93.540	0.000
Error	1134.682	77	14.736	-	-
Total (Corrected)	4119.550	79	-	-	-

Source: SPSS Output, **Year:** 2026

Even after prior ability was statistically controlled, the instructional model retained a significant effect on posttest reasoning scores ($F = 93.540$; $p < 0.001$). Together, the learning model

and pretest score accounted for 72.5% of the variance in posttest outcomes, leaving the remaining 27.5% unexplained by the model. In practical terms, this reduces the likelihood that the observed posttest difference was due solely to differences in the groups' initial ability.

B. Discussion

The analyses converge on a single finding: within this sample, students taught with PBL achieved significantly higher mathematical reasoning scores than students taught conventionally on the topic of number patterns and sequences, and the difference persisted after prior ability was controlled. The direction of this result is consistent with earlier studies on other topics, in which PBL produced meaningful gains in reasoning ability in social arithmetic (Abidah et al., 2021; Afifah et al., 2018) and outperformed direct instruction in circle geometry whether or not it was paired with tools such as GeoGebra (Sugandi et al., 2020). The present study extends that line of evidence to a topic and a school level on which it had not previously been tested.

The theoretical explanation for this advantage lies in the correspondence between the phases of PBL and the indicators used to score reasoning. Arends (2008) describes PBL as a sequence that begins by orienting students to a contextual problem before any formal exposition, continues through organized investigation, and ends with the presentation and evaluation of a solution. Each of these phases requires exactly the cognitive act that one of the reasoning indicators measures: the opening problem obliges students to notice a regularity and state a conjecture; guided investigation obliges them to manipulate the pattern mathematically and gather evidence; and the presentation phase obliges them to justify their generalization and to examine the validity of arguments offered by other groups (NCTM, 2000). Conventional expository instruction asks for none of these acts explicitly, since the generalization is supplied by the teacher and the student's task is to apply it. The scoring rubric used here therefore rewarded precisely the behaviors that the experimental treatment practiced repeatedly and the control treatment did not, which offers a coherent account of why the posttest gap emerged on these particular indicators.

The characteristics of the topic plausibly amplified that mechanism. Number patterns and sequences require students to identify a regularity, express it symbolically as a general form, and then establish that the general form holds, and previous research has shown that it is the latter two steps, rather than the initial recognition of a pattern, that students most often fail (Suhartatik et al., 2023; Utomo et al., 2022). PBL gave the experimental group structured and repeated practice at exactly those steps, first individually and then through group discussion in which conjectures had to be defended. Related work in Histogram similarly reports that PBL improves the later stages of mathematical problem solving, in particular planning and verification, more than the initial comprehension stage (Damayati & Sutarni, 2023). The convergence of these findings suggests that

the topic's demand for generalization and justification is one reason the effect observed here was large rather than marginal.

The ANCOVA result strengthens the internal validity of this interpretation without extending it further than the design allows. Because the effect of the instructional model remained significant after pretest scores were controlled, the posttest difference cannot be explained by the two groups having started from different baselines. It does not follow that the entire difference is attributable to PBL as such. In a quasi-experimental design using intact classes, the treatment is delivered as a package, and factors that accompanied it, including the novelty of a new learning format, the increased amount of group interaction, and possible differences in student motivation or in the intensity of teacher attention, cannot be separated statistically from the model itself. A partial eta squared of 0.549 is best read as the magnitude of the effect of the treatment condition as a whole, of which the PBL syntax is the defining but not necessarily the only active component.

The observation data point in the same direction and carry the same qualification. Using the observation sheet described in the method section, student learning activity in the experimental class was recorded at 87.5%, compared with 62.5% in the control class, with the largest differences on the indicators of active discussion and collaborative group work in solving problems, together with presenting/articulating reasoning results in front of the class. Increased student engagement under PBL has also been reported elsewhere (Jami'atun et al., 2025). Since these data are descriptive and were collected without blinding of the observer, they are best treated as a description of how the two classrooms differed in process, not as independent evidence that PBL caused the score gains.

Several limitations bound the scope of these conclusions. The sample consisted of two intact classes in a single madrasah, so the participating students shared one school culture, one curriculum implementation, and one mathematics teacher; with only two clusters, any class-level characteristic, whether classroom climate or peer composition, is completely confounded with the treatment condition and cannot be estimated separately. The content was restricted to a single topic, the treatment lasted only four meetings, and retention was not measured after the posttest, so the durability of the effect is unknown. The absence of blinding for the teacher and the observer leaves room for expectancy effects. These constraints do not undermine the finding within its context, but they do mean it should be regarded as evidence from one school rather than as a general estimate of the effect of PBL.

IV. CONCLUSIONS AND SUGGESTIONS

A. Conclusions

Within the context of this study, that is, two intact eighth-grade classes at MTsN 1 Polewali Mandar working on number patterns and sequences during the 2025/2026 academic year, the

Problem-Based Learning model was effective in improving students' mathematical reasoning ability. Students in the PBL class obtained a significantly higher posttest mean (78.75) than students in the conventional class (67.40), $t(78) = -11.412$, $p < 0.001$, with a large effect size (Cohen's $d = 2.55$), and this difference persisted after prior achievement was statistically controlled, $F(1,77) = 93.540$, $p < 0.001$, partial eta squared = 0.549. The coefficient of determination of the ANCOVA model, $R^2 = 0.725$, describes the variance in posttest scores explained jointly by the instructional model and the pretest score, and is not an estimate of the contribution of PBL by itself. Because the design was quasi-experimental and used intact classes from one school, the finding is best stated as an association between the PBL learning condition and higher reasoning scores in this setting, rather than as a general causal claim about the model.

Accordingly, PBL can be recommended as a workable alternative for teaching number patterns and sequences at the Madrasah Tsanawiyah level under conditions comparable to those studied here, and its wider adoption would need to be supported by further evidence from other schools, topics, and student populations.

B. Suggestions

For teachers, the results suggest that PBL is worth trying as an alternative approach for number patterns and sequences in classes similar to those studied here. Its benefit depends on the quality of the opening problem, which must genuinely require students to notice a regularity, propose a conjecture, and justify it, rather than to follow a demonstrated procedure. For schools and policymakers, support for teacher training in designing and facilitating problem-based lessons would allow the model to be tested consistently across other mathematics topics. Given that the present evidence comes from a single school, such support is better framed as a controlled trial accompanied by evaluation than as a blanket policy of adoption. For future researchers, replication with a larger number of classes drawn from several schools would allow the class-level confounding inherent in a two-cluster design to be addressed, for example through multilevel analysis. Studies extending the treatment period, adding a delayed posttest to examine retention, and testing the model on other topics and at other levels would also clarify how far the present result generalizes.

Subsequent work might further examine moderator variables such as learning style, mathematical disposition, or self-efficacy (Fauziah & Kusnandi, 2025; Khardita & Agoestanto, 2023), or combine PBL with supporting tools such as GeoGebra, in order to identify the conditions under which the model is most effective.

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