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Reconceptualising Mathematical Problem Solving and Higher-Order Thinking: A Comparative Analysis of Lesson Study-Based Instruction and Conventional Teaching

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ABSTRACT
This study aimed to examine the effect of Lesson Study-based instruction on students' Higher-Order Thinking Skills (HOTS) and Mathematical Problem-Solving abilities regarding similarity. A quantitative approach with a quasi-experimental nonequivalent control group design was employed. Two intact Grade VIII classes at SMP Negeri 1 Maja, Majalengka Regency, were purposively selected as the experimental group (receiving Lesson Study-based instruction) and the control group (receiving conventional instruction). Data were collected using a validated essay test of six items—three measuring Mathematical Problem-Solving skills based on Polya's framework and three measuring HOTS aligned with the revised Bloom's Taxonomy indicators. The test showed high validity and reliability after piloting. Data analysis included normality tests (Shapiro-Wilk), homogeneity of variance tests (Levene's test), independent samples t-tests to compare post-test and normalized gain (N-gain) scores, and effect size interpretation based on Hake's classification. The results revealed a significant improvement in both post-test and N-gain scores in the experimental group compared to the control group, indicating that Lesson Study-based instruction effectively enhances students' advanced cognitive skills in mathematics. This study supports integrating collaborative lesson design and reflective teaching practices in mathematics education to improve problem-solving and higher-order thinking.

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INTRODUCTION

In recent years, increasing attention has been directed toward strengthening students' Higher-Order Thinking Skills (HOTS) and mathematical problem-solving abilities, particularly within the similarity domain (*kesebangunan*), a critical component of the junior high school mathematics curriculum. These competencies are considered vital for preparing learners to address complex, real-world challenges and to meet the cognitive demands of 21st-century education and work. International assessments such as the Programme for International Student Assessment (PISA) emphasize mathematical reasoning and problem-solving as key indicators of educational quality. As a result, many countries, including Indonesia, have undertaken curricular reforms to embed HOTS within classroom instruction. HOTS is defined within this framework as the ability to analyze, evaluate, and create, particularly relevant in solving geometry problems involving proportional reasoning, spatial visualization, and abstraction. As Zebua (2024) and Kristiyono (2018) noted, nurturing students' advanced cognitive skills is an educational imperative and a response to global shifts in learning.

A growing body of research has demonstrated that HOTS-oriented instruction significantly enhances students' conceptual understanding, reasoning abilities, and cognitive engagement in mathematics. For example, Beddu (2019) and Alaudin & Missouri (2023) reported that pedagogical strategies targeting cognitive complexity promote deeper mathematical comprehension. Problem-solving is a central process in HOTS, engaging students in synthesizing knowledge, identifying relationships, and applying logical reasoning. Doorman et al. (2007) and Santos-Trigo (2020) highlight that strategic reasoning and metacognitive reflection are integral to problem-solving proficiency, while Jäder et al. (2020) and Atweh et al. (2003) observe a global trend toward problem-centred mathematics education. This trend is evident in Indonesia's increasing scholarly focus on mathematical problem-solving as a core 21st-century competency (Wahyuni et al., 2024).

Nevertheless, recent studies have documented persistent difficulties among Indonesian students in mastering the concept of similarity. Students frequently exhibit confusion between similarity and congruence, misunderstand proportional relationships, and struggle to apply geometric principles effectively. Jatisunda and Nahdi (2019) identified conceptual gaps in basic geometry that disrupt learning trajectories in related topics, including trigonometry. Dedy and Sumiaty (2017) attributed students' misconceptions to the lack of systematic instructional design, while Fadilah and Bernard (2021) noted widespread procedural errors in solving contextual problems involving similarity. Data from large-scale assessments, such as TIMSS, analyzed by Prasetyo and Rudhito (2016), further reveal Indonesian students' consistent underperformance in geometry tasks. Although alternative instructional methods such as jigsaw learning (Shaufia & Ranti, 2020) and computer-based media (Fitriyani et al., 2020) have been explored to improve outcomes, conceptual understanding in similarity remains underdeveloped.

Another key issue is the persistence of teacher-centred instructional models prioritizing procedural knowledge over conceptual understanding. Many classrooms reduce the topic of similarity to the application of formulas, neglecting the reasoning processes related to proportionality and spatial representation. Solihah, Muhtadi, and Sukirwan (2025) observed that such practices contribute to students' difficulty in grasping both the conceptual and procedural aspects of similarity. Similarly, Hamid (2025) and Fajriah & Asiskawati (2015) argue that traditional pedagogical practices fail to cultivate students' creativity and exploration. In contrast, constructivist perspectives advocated by Rangkuti (2014) emphasize the importance of active learning, reflection, and conceptual construction—foundational principles for developing a deep understanding of geometric similarity.

To address the aforementioned pedagogical challenges, Lesson Study has emerged as a promising professional development model that supports collaborative instructional design and reflective teaching practice. Research by Yoshida (2012) and Lewis (2016) shows that Lesson Study enhances teachers' pedagogical content knowledge and enables them to implement tasks that promote HOTS and problem-solving. In geometry instruction, Lesson Study has been linked to developing student skills in proportional reasoning and logical justification (Huang & Shimizu, 2016; Ding et al., 2024; Ní Shúilleabháin, 2016). Despite the promise of this approach, there remains a lack of empirical studies employing rigorous designs—such as quasi-experiments—to compare the effectiveness of Lesson Study with traditional instruction, particularly in developing HOTS and problem-solving abilities related to similarity. Gholami (2024) and Purnomo et al. (2024) emphasize the importance of evidence-based investigations into the differential impact of various pedagogical models, while Siew and Basari (2024) highlight the potential of integrated, student-centred strategies to foster both individual and collaborative cognitive development. These observations reveal a significant gap in the empirical evaluation of Lesson Study's impact on higher-order reasoning in the context of geometry learning.

To fill this research gap, the present study aims to examine the effects of Lesson Study-based instruction on students' Higher-Order Thinking Skills (HOTS) and Mathematical Problem-Solving abilities in the context of similarity. Using a quasi-experimental design with nonequivalent control groups, this study investigates whether students who receive Lesson Study-based instruction demonstrate superior cognitive performance compared to those taught using conventional methods. The novelty of this research lies in its integration of validated assessment tools aligned with Polya's problem-solving model and the revised Bloom's Taxonomy, as well as its application of Lesson Study as a context-specific intervention in Indonesian junior secondary education. By comparing the effectiveness of two instructional approaches in a controlled setting, this study provides empirical evidence that contributes to current discourse on mathematics education reform and offers practical implications for fostering reflective, student-centred teaching practices.

METHODS

This study employed a quantitative approach with a quasi-experimental design, specifically the nonequivalent control group design. This design was selected due to the researcher's inability to randomly assign participants to treatment groups, as the study used intact classes available at the research site. According to Creswell (2012) and Cohen, Manion, and Morrison (2018), such a design is appropriate for comparing the outcomes of instructional interventions when complete randomisation is not feasible, while still enabling causal inference under controlled conditions.

The research was conducted at SMP Negeri 2 Maja, Majalengka Regency, during the second semester of the 2024/2025 academic year. The study involved two Grade VIII classes with comparable academic backgrounds. Class VIII-A was assigned as the experimental group, receiving Lesson Study-based instruction, while Class VIII-B served as the control group and received conventional instruction. The two classes were selected through purposive sampling, considering the mathematics teacher's readiness to collaborate in the Lesson Study process and the school's support for research activities. The independent variable was the type of instruction (Lesson Study vs. conventional). In contrast, the dependent variables were students' Higher-Order Thinking Skills (HOTS) and mathematical problem-solving abilities in similarity.

Data were collected using an essay-type test instrument consisting of six items. Three items were designed to measure mathematical problem-solving skills based on Polya's four-step framework (understanding the problem, devising a plan, carrying out the plan, and reviewing the solution). The remaining three items assessed HOTS, aligned with the revised Bloom's Taxonomy indicators, explicitly focusing on analysis, evaluation, and creation. All items were developed in alignment with the relevant basic competencies in the Indonesian mathematics curriculum for the similarity topic.

To ensure the instrument's validity and reliability, content validation was carried out by two university lecturers and one experienced mathematics teacher. The instrument was then piloted with 30 students from a different school with similar characteristics. The trial results demonstrated strong psychometric properties: an average content validity coefficient of 0.81, Cronbach's alpha of 0.82, and balanced difficulty and discrimination indices. Although the test covered two cognitive constructs—HOTS and problem-solving—scores from all items were combined to generate an overall cognitive performance score. This approach allowed for a comprehensive yet practical comparison between instructional groups.

The research followed four main stages: planning, implementation, reflection, and documentation. In the planning phase, the researcher collaborated with the classroom teacher to co-develop detailed lesson plans, student worksheets, and supporting instructional media tailored for the Lesson Study cycle. The implementation phase consisted of eight sessions, each lasting 2 × 40 minutes. A Plan-Do-See model was adopted, in which one teacher conducted the lesson while another observed and took systematic field notes. After each lesson, collaborative reflection meetings were held to analyze instructional effectiveness and refine subsequent practices. Teaching sessions were documented through video recordings and reflective journals.

Pre-tests and post-tests were administered to the experimental and control groups to evaluate learning outcomes. Data analysis procedures included the Kolmogorov–Smirnov test for normality, Levene's test for homogeneity of variance, and independent samples t-tests to assess differences in post-test scores and learning gains between groups. To quantify learning improvement, normalized gain (N-gain) scores were calculated. The interpretation of N-gain scores followed Hake's (1999) classification, where $g > 0.7$ indicates high gain, $0.3 \leq g \leq 0.7$ indicates moderate gain, and $g < 0.3$ indicates low gain. Throughout the study, attention was given to ensuring internal and external validity to maintain the scientific rigour of the findings.

RESULTS AND DISCUSSION

Result

Table 1 presents the descriptive statistics of the pre-test scores, post-test scores, and N-gain values for the experimental and control groups to provide an initial overview of the participants' performance in both groups.

Table 1. Descriptive Statistics of Pre-test, Post-test Scores, and N-gain by Group

Group	N	Pre-test Mean (SD)	Post-test Mean (SD)	N-gain Mean (SD)
Experimental	30	59.06 (7.80)	74.12 (8.15)	0.37 (0.12)
Control	30	60.39 (7.32)	65.29 (7.06)	0.13 (0.09)

The descriptive statistics in Table 1 show that the experimental and control groups had comparable mean pre-test scores, with the experimental group scoring 59.06 (SD = 7.80) and the control group scoring 60.39 (SD = 7.32). After the intervention, the experimental group demonstrated a substantial increase in mean post-test scores to 74.12 (SD = 8.15), whereas the control group showed a more modest improvement to 65.29 (SD = 7.06). Correspondingly, the mean N-gain value, which reflects the normalized improvement, was higher in the experimental group (0.37, SD = 0.12) compared to the control group (0.13, SD = 0.09), indicating that the experimental group experienced a greater relative gain in performance following the treatment. Next, the normality of the post-test data for each group was assessed using the Shapiro-Wilk test to ensure the appropriate selection of statistical tests.

Table 2. Normality Test Results (Shapiro-Wilk) for Post-test Scores

Group	Statistic	df	p-value	Normality
Experimental	0.967	30	0.340	Normal
Control	0.870	30	0.004	Not Normal

The results of the Shapiro-Wilk test for normality, presented in Table 2, indicate that the post-test scores of the experimental group are normally distributed ($W = 0.967$, $p = 0.340 > 0.05$). In contrast, the post-test scores of the control group deviate significantly from normality ($W = 0.870$, $p = 0.004 < 0.05$). These findings suggest that the assumption of normality holds for the experimental group but is violated for the control group, which should be considered when selecting appropriate statistical tests for further analysis. Thereafter, the homogeneity of variances for the post-test scores between the groups was tested using Levene's Test to determine whether the variances of the two groups were equal.

Table 3. Homogeneity of Variance Test (Levene's Test) for Post-test Scores

Test Statistic	df1	df2	p-value
0.723	1	58	0.398

The Levene's test for homogeneity of variances yielded a test statistic of 0.723 with degrees of freedom 1 and 58, and a p-value of 0.398. Since the p-value is greater than the significance level of 0.05, the assumption of equal variances between the experimental and control groups is not violated. This indicates that the variances of post-test scores in both groups can be considered statistically homogeneous, supporting parametric tests assuming equal variances. Finally, an independent samples t-test was conducted to compare the post-test and N-gain scores between the experimental and control groups.

Table 4. Independent Samples t-Test for Post-test and N-gain Scores

Variable	t	df	p-value	Interpretation
Post-test	4.997	58	< 0.001	Significant difference
N-gain	7.743	58	< 0.001	Highly significant difference

The independent samples t-test results show a statistically significant difference in post-test scores between the experimental and control groups ($t = 4.997$, $df = 58$, $p < 0.001$). This indicates that the intervention had a meaningful effect on participants' post-test performance. Moreover, the analysis of N-gain scores reveals an even more pronounced difference between the two groups ($t = 7.743$, $df = 58$, $p < 0.001$), demonstrating that the experimental group achieved a significantly higher normalised gain than the control group. These findings prove that the treatment effectively enhanced learning outcomes relative to the control condition.

Discussion

The results of this study indicate that the experimental group experienced significantly greater improvements in learning performance than the control group. The most prominent finding from the analysis is that the experimental group's post-test scores ($M = 74.12$, $SD = 8.15$) were significantly higher than those of the control group ($M = 65.29$, $SD = 7.06$), as confirmed by the independent samples *t*-test ($t = 4.997$, $df = 58$, $p < 0.001$). Additionally, the experimental group achieved a substantially higher mean normalized gain (N-gain) score ($M = 0.37$, $SD = 0.12$) than the control group ($M = 0.13$, $SD = 0.09$), with the difference being statistically significant ($t = 7.743$, $df = 58$, $p < 0.001$). These results suggest that the Lesson Study-Based Instruction implemented in the experimental group had a meaningful and measurable effect on students' learning outcomes. Furthermore, the Shapiro-Wilk test showed that the post-test scores of the experimental group were normally distributed, while those of the control group were not. Nevertheless, Levene's test indicated homogeneity of variances between the two groups ($p = 0.398$), justifying parametric tests for further analysis. Collectively, the evidence underscores the effectiveness of Lesson Study-Based Instruction, particularly in improving relative gains as captured by N-gain scores.

These findings are in line with prior studies. For instance, Apino and Retnawati (2017) demonstrated that instructional designs targeting higher-order mathematical thinking significantly improved student post-test performance. Similarly, Hansen and Hadjerrouit (2023) reported that embedding computational thinking within a Use-Modify-Create framework enhanced students' mathematical problem-solving skills. By contrast, Abdullah et al. (2019) found no significant gains in student performance despite curricular emphasis on higher-order thinking, highlighting the crucial role of instructional implementation. The current study's substantial N-gain results, especially within the experimental group, may reflect more effective engagement in cognitively demanding tasks. Moreover, these gains align with recent arguments emphasizing the importance of intuitive and flexible thinking in mathematical problem-solving (Suwarto et al., 2023; Ye et al., 2024), which Lesson Study-Based Instruction in this study may have successfully fostered.

A possible explanation for the observed learning gains is that Lesson Study-Based Instruction created more opportunities for active engagement and deeper conceptual understanding. Baptista et al. (2025) and Richit et al. (2024) emphasize that lesson study's collaborative and iterative nature empowers teachers to design student-centered, conceptually grounded learning experiences. In STEM education, this structure encourages inquiry-based instructional tasks that support student engagement and reasoning (Flanagan et al., 2024; Herlanti et al., 2025). The lesson study framework—goal setting, collaborative lesson planning, observation, and reflective discussion—supports more effective cognitive processing by enabling teachers to anticipate and respond to student thinking (Skott, 2024; Yun et al., 2024). This contrasts with conventional approaches, which often lack systematic feedback and refinement, limiting their responsiveness to students' conceptual difficulties (Marques Santinha et al., 2024). Furthermore, the emphasis on teacher noticing within lesson study cycles cultivates a responsive learning environment that promotes metacognitive development and sustained learning (Brown, 2024; Yun et al., 2024). These structural and pedagogical features may explain the effectiveness of Lesson Study-Based Instruction in fostering meaningful mathematical understanding.

Nonetheless, several limitations should be acknowledged. First, this study was conducted at a single educational institution, which may constrain the generalizability of the findings. Second, although the sample size was adequate for statistical testing, it may not reflect the broader diversity of student populations regarding prior achievement and demographic characteristics. Despite these limitations, the findings have important implications for instructional practice. Integrating Lesson Study-Based Instruction into routine teaching may enhance students' conceptual mastery and learning engagement. Educators are encouraged to adopt structured, collaborative teaching models to address learning gaps and support academic growth systematically. Future research should explore the long-term effects of such interventions, particularly concerning knowledge retention and transferability. Additionally, investigating the differential impacts of the intervention across various student subgroups, such as those with lower prior achievement, could provide deeper insights into its broader applicability and equity outcomes.

CONCLUSION

This study set out to compare the effectiveness of a Lesson Study-based instructional approach with conventional teaching methods in improving students' Mathematical problem-solving and Higher-Order Thinking skills. The findings indicate that while both groups started with comparable pre-test scores, the experimental group demonstrated a significantly greater improvement in post-test performance and N-gain values. Statistical analysis confirmed that the difference in gains between the two groups was highly significant. These results suggest that the Lesson Study-based instruction had a positive and meaningful impact on students' Mathematical problem-solving and Higher-Order Thinking abilities. This supports the hypothesis that collaborative and reflective teaching practices can enhance instructional effectiveness in these domains. A limitation of this study is the relatively small sample size, which may affect the generalisability of the results. Future studies should consider replicating the study with a larger and more diverse sample to strengthen the external validity of the findings. In addition, further research is needed to explore the long-term effects of Lesson Study-based instruction on various aspects of students' mathematical cognition and teacher development. In conclusion, this study contributes to a growing body of evidence supporting the use of Lesson Study as an effective model for improving teaching practice and students' Mathematical problem-solving and Higher-Order Thinking skills. These findings have important implications for educational practice, particularly in contexts that foster collaborative professional development among teachers.

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