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Experiential learning and geometrical thinking among grade 8 students: A quasi-experimental study

Yani Supriani*
Universitas Serang Raya, INDONESIA

Indri Lestari
Universitas Serang Raya, INDONESIA

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Abstract

Background: Experiential learning connects concrete experience, reflection, conceptualization, and application. This approach is relevant to geometry learning because students are expected to reason about geometric properties, relationships, and applications rather than merely recognize geometric objects.
Aims: This study examines differences in geometrical-thinking improvement between Grade 8 students receiving experiential learning and those receiving conventional mathematics instruction.
Method: A quasi-experimental pretest–posttest control-group design was employed with 50 Grade 8 students at SMP Negeri 42 Batam, Indonesia. The participants comprised 25 students in an experimental group and 25 in a control group selected through purposive sampling within existing school-based classes. The experimental group received instruction structured around Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation, whereas the control group received conventional instruction. Data were collected using a four-item written essay test assessing geometrical thinking in learning the Pythagorean theorem. Group differences in score changes were analyzed, with baseline-adjusted analysis used as a supplementary analysis.
Results: The experimental group showed greater improvement than the control group, with mean gains of 29.75 and 6.50 points, respectively, on a 0–100 scale. The between-group difference in change was significant ($t(48) = 3.97$, $p < .001$), with a large effect (Cohen's $d = 1.12$).
Conclusion: The findings suggest that experiential learning is associated with greater improvement in overall geometrical-thinking performance than conventional instruction. The findings should be interpreted within the limitations of the quasi-experimental design, existing class arrangements, single-school setting, and short intervention period.

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INTRODUCTION

Geometrical thinking is an important component of mathematics learning because it involves students' ability to recognize geometric objects, examine their properties and relationships, interpret spatial information, and reason about geometric situations. At the secondary-school level, students are expected to move beyond visual recognition toward increasingly analytical forms of geometric reasoning. Research indicates that geometric thinking remains an important concern in mathematics education, with students showing variation in their attainment of different levels of geometric thinking (Naufal et al., 2021; Trimurtini et al., 2022). The Van Hiele framework provides an important perspective for understanding this development through five levels: visualization, analysis, informal deduction, formal deduction, and rigor. Empirical studies have reported that many secondary-school students remain at relatively lower levels of geometric thinking (Al Afgoni et al., 2020; Putri et al., 2024; Susanto & Mahmudi, 2021). Research focusing on the Pythagorean theorem has also

***Corresponding author:**
Yani Supriani, Universitas Serang Raya, Indonesia
yani.supriani2@gmail.com

demonstrated the relevance of the Van Hiele framework for examining junior high school students' geometrical thinking (Arnita et al., 2024).

The difficulty of developing geometrical thinking is also reflected in students' geometry problem solving. Students may experience difficulties when identifying geometric properties, establishing relationships among geometric elements, or formulating conclusions from geometric information. Previous research has associated problem-solving performance with students' levels of geometric thinking and reported difficulties among students who have not developed higher levels of geometric reasoning (Khaerunnisa & Adirakasiwi, 2023; Mahfudy & Afriana, 2024; Widiyaningsih et al., 2020). These findings suggest that geometry instruction should provide opportunities for students to observe, investigate, discuss, conceptualize, and apply geometric relationships rather than rely exclusively on direct transmission of mathematical information.

Experiential learning provides a potentially relevant instructional perspective because it positions experience as a basis for constructing knowledge. The experiential learning cycle consists of four interconnected processes: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation (Kolb, 2015). In mathematics education, previous studies have applied experiential learning to mathematical justification and conjecturing (Supriani et al., 2019; Supriani & Sholahudin, 2019), arithmetic and geometry learning (Uyen et al., 2022), and mathematical connections (Buakieow & Kijkuakul, 2023). More recent research has also examined active and experiential learning among eighth-grade students, demonstrating its relevance to mathematics learning outcomes (Žakelj et al., 2024). These studies indicate that experience-oriented learning can connect students' activities, reflection, conceptual understanding, and application, although its outcomes have generally been examined through achievement, problem solving, mathematical connections, or other specific competencies.

Experiential learning is particularly relevant to geometry because geometric understanding requires students to observe figures and situations, identify characteristics, examine relationships, formulate conceptual explanations, and apply concepts to new problems. The experiential cycle can provide opportunities for students to interact with geometric situations, investigate relationships, reflect on observations, construct conceptual understanding, and apply their ideas in subsequent problems (Kolb, 2015; Uyen et al., 2022). Experiential learning and the Van Hiele framework therefore offer complementary perspectives: experiential learning describes a process through which knowledge may be constructed from experience, whereas Van Hiele describes increasing sophistication in students' geometric thinking (Kolb, 2015; van Hiele, 1986). Their alignment, however, does not imply that implementing experiential learning automatically moves students through Van Hiele levels. Rather, experiential learning may provide instructional conditions that support increasingly analytical forms of geometrical thinking.

Despite these findings, a gap remains in the empirical connection between experiential learning and geometrical thinking. Existing experiential-learning studies have examined mathematical justification, conjecturing, connections, achievement, problem solving, and arithmetic or geometry learning (Buakieow & Kijkuakul, 2023; Supriani et al., 2019; Supriani & Sholahudin, 2019; Uyen et al., 2022; Žakelj et al., 2024), whereas research on geometrical thinking has frequently focused on identifying Van Hiele levels, describing students' difficulties, or evaluating Van Hiele-oriented instruction (Naufal et al., 2021; Putri et al., 2024; Trimurtini et al., 2022). Comparatively limited attention has been given to an instructional sequence explicitly organized around the experiential learning cycle while using geometrical thinking as the primary outcome in a comparison between experiential-learning and conventional-instruction groups. This gap is particularly relevant to Grade 8 geometry, including the Pythagorean theorem, where students are expected to move from recognizing geometric properties toward examining relationships and applying geometric reasoning.

The present study addresses this gap by examining experiential learning as a structured instructional approach for Grade 8 students learning the Pythagorean theorem. Using a quasi-experimental pretest–posttest control-group design, the study compares students receiving instruction structured around Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation with students receiving conventional instruction. The study focuses specifically on geometrical thinking rather than general mathematics achievement. Its contribution is therefore not the introduction of a new experiential learning model, but empirical evidence concerning the application of an established experiential learning cycle to geometrical thinking in Grade 8 geometry. Accordingly, this study aims to examine whether Grade 8 students who participate in experiential learning demonstrate different geometrical-thinking outcomes from students who receive conventional instruction.

LITERATURE REVIEW

Geometrical thinking represents a fundamental dimension of mathematical cognition that enables students to interpret spatial representations, identify geometric properties, establish relationships, and construct logical explanations of mathematical phenomena. Its development is particularly important in secondary mathematics education, where learners are expected to progress from recognizing geometric figures toward understanding their structural characteristics and applying deductive reasoning (Mudhefi et al., 2024; Seah & Horne, 2020). The theoretical framework proposed by van Hiele (1986) conceptualizes geometrical thinking as a developmental progression involving visualization, analysis, informal deduction, formal deduction, and rigor. These levels describe increasingly sophisticated forms of geometric reasoning, emphasizing the importance of instructional experiences that correspond to students' existing conceptual understanding (van Hiele, 1986). Naufal et al. (2021) highlighted the relevance of the Van Hiele framework for examining geometric cognition and the potential contribution of metacognitive processes to students' mathematical understanding. Similarly, Trimurtini et al. (2022) identified geometrical thinking as a continuing research concern in mathematics education, particularly regarding the development of students' reasoning abilities and instructional approaches. Empirical investigations have demonstrated considerable variation in students' geometric thinking levels, indicating that progression toward advanced reasoning cannot be assumed solely from grade-level advancement (Susanto & Mahmudi, 2021). Putri et al. (2024) further examined junior high school students' geometric abilities through the Van Hiele perspective, emphasizing the relationship between conceptual understanding and students' demonstrated levels of geometric reasoning. These findings suggest that geometry education requires instructional strategies that systematically connect visual representations, analytical reasoning, and conceptual interpretation rather than emphasizing procedural knowledge alone. Consequently, geometrical thinking provides an appropriate theoretical foundation for investigating instructional approaches intended to strengthen students' understanding of geometric relationships and mathematical applications.

Despite its significance, the development of geometrical thinking remains challenging because students frequently encounter difficulties interpreting geometric information, recognizing relevant properties, and connecting mathematical representations with appropriate reasoning procedures. Al Afgoni et al. (2020) investigated students' achievement of lower levels of geometrical thinking, illustrating the importance of considering instructional characteristics when examining geometric understanding. Difficulties become particularly evident when mathematical tasks require learners to transform visual information into conceptual relationships or justify the procedures used to solve geometric problems (Ayeh, 2025; Hlongwana et al., 2025; Mahlaba & Mudaly, 2022; Maifa et

al., 2025). Khaerunnisa and Adirakasiwi (2023) examined students' mathematical thinking processes in solving contextual problems through the Van Hiele framework, providing insights into the relationship between geometric reasoning and problem-solving performance. Similarly, Mahfudy and Afriana (2024) identified difficulties in geometry problem solving across different levels of Van Hiele thinking, suggesting that students' reasoning characteristics influence their approaches to mathematical tasks. Widiyaningsih et al. (2020) also investigated problem-solving ability and self-efficacy in relation to geometric thinking levels, demonstrating the relevance of cognitive and learner-related characteristics in geometry education. Within the Pythagorean theorem, students must coordinate their understanding of right triangles, geometric measurements, and relationships among side lengths to formulate mathematically appropriate solutions. Arnita et al. (2024) specifically examined junior high school students' geometrical thinking in Pythagorean theorem learning using Van Hiele theory, reinforcing the relevance of this framework to the mathematical content addressed in the present study. Collectively, these investigations indicate that difficulties in geometry cannot be adequately addressed through procedural exercises without considering how students interpret, organize, and apply geometric relationships. Accordingly, instructional environments that encourage exploration, mathematical communication, reflection, and conceptual reconstruction may provide meaningful opportunities to support the development of geometrical thinking.

Experiential learning offers a constructivist-oriented instructional perspective in which knowledge emerges through the transformation of experience into conceptual understanding and subsequent application. Kolb (2015) conceptualized experiential learning as a cyclical process comprising Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation, with each component contributing to the development and refinement of knowledge. Concrete Experience introduces learners to meaningful situations that provide an initial basis for examining mathematical phenomena through direct engagement with objects, representations, or contextual problems (Kolb, 2015). Reflective Observation subsequently encourages students to reconsider their experiences, identify emerging patterns, compare alternative interpretations, and evaluate the relationships observed during learning activities (Kolb, 2015). Abstract Conceptualization facilitates the transformation of these observations into mathematical principles, conceptual explanations, and generalized relationships that extend beyond the original learning situation (Kolb, 2015). Active Experimentation completes the learning cycle by allowing students to apply their developing understanding to unfamiliar problems and examine the usefulness of previously constructed mathematical concepts (Kolb, 2015). Within mathematics education, Supriani et al. (2019) investigated experiential learning as an approach to developing students' mathematical justification skills, emphasizing its relevance to reasoning-oriented learning. Supriani and Sholahudin (2019) further explored experiential learning in relation to students' ability to formulate mathematical conjectures, illustrating its potential application to mathematical inquiry and conceptual exploration. These studies provide a conceptual basis for considering experiential learning as an instructional approach that integrates active participation with reflective and analytical mathematical processes. Therefore, experiential learning may be particularly relevant to geometry instruction because it provides a structured sequence through which students can investigate geometric representations, construct mathematical relationships, and apply their understanding to problem-solving situations.

The application of experiential learning in mathematics education has received increasing attention because experience-oriented instructional activities can create opportunities for students to connect mathematical concepts with meaningful learning situations. Uyen et al. (2022) investigated the effectiveness of experiential learning in sixth-grade arithmetic and geometry, providing empirical evidence concerning its application to elementary mathematics instruction.

Their research contributes to understanding how experience-based mathematical activities can be incorporated into classroom learning rather than treating mathematical concepts exclusively as abstract procedures. Buakieow and Kijkuakul (2023) examined the integration of experiential learning and mathematical tasks to enhance ninth-grade students' mathematical connection abilities in similarity, extending the approach to secondary-level geometry content. This investigation is particularly relevant because mathematical connections require learners to recognize relationships among concepts, representations, and problem situations that are also important in geometrical thinking (Cantillo-Rudas et al., 2024; Jablonski & Ludwig, 2023; Jawad, 2022; Žakelj & Klančar, 2022). More recently, Žakelj et al. (2024) investigated active and experiential learning among eighth-grade students, providing further evidence concerning the relevance of student-centered instructional experiences to mathematics learning outcomes. Although these investigations addressed different mathematical competencies and educational contexts, they collectively support the importance of connecting instructional experiences with reflection, conceptual development, and mathematical application. From a theoretical perspective, experiential learning and Van Hiele theory offer complementary explanations of geometry learning, with the former describing processes of knowledge construction and the latter characterizing increasingly sophisticated forms of geometric reasoning (Kolb, 2015; van Hiele, 1986). Nevertheless, conceptual compatibility between these frameworks should not be interpreted as evidence that participation in experiential learning necessarily produces progression across specific Van Hiele levels. Rather, experiential activities may establish instructional conditions that encourage students to examine geometric properties, articulate mathematical relationships, and engage in analytical reasoning. This conceptual relationship provides a rationale for investigating whether experiential learning is associated with improvements in students' overall geometrical-thinking performance within secondary-school geometry instruction.

Although previous research has established the relevance of experiential learning to mathematical justification, conjecturing, mathematical connections, and learning outcomes, its specific relationship with geometrical thinking requires further empirical investigation. Existing experiential-learning studies have primarily examined mathematical competencies or achievement outcomes without consistently positioning overall geometrical thinking as the principal dependent variable (Supriani et al., 2019; Supriani & Sholahudin, 2019; Uyen et al., 2022; Buakieow & Kijkuakul, 2023). Meanwhile, research grounded in Van Hiele theory has frequently concentrated on identifying students' geometric thinking levels, examining reasoning difficulties, and describing characteristics of geometric understanding (Naufal et al., 2021; Susanto & Mahmudi, 2021; Putri et al., 2024). This distinction indicates a need for studies that explicitly connect experience-oriented instructional sequences with the assessment of geometrical-thinking performance in classroom settings. The Pythagorean theorem provides a relevant instructional context because its conceptual understanding requires students to interpret geometric representations, recognize relationships among triangle elements, and apply mathematical reasoning to contextual problems. Furthermore, investigating Grade 8 students is educationally relevant because learners at this stage are expected to strengthen their ability to connect visual geometric information with analytical explanations and mathematical applications (Hatisaru, 2020; Jablonski & Ludwig, 2023; Žakelj & Klančar, 2022). A quasi-experimental pretest–posttest control-group design offers a practical approach for comparing changes in geometrical-thinking performance between students experiencing different instructional conditions within existing school classes. Nevertheless, the absence of individual random assignment requires careful consideration of initial group differences and limits the extent to which observed improvements can be attributed exclusively to instructional treatment. Addressing this research gap, the present study examines experiential learning structured around Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation in comparison with

conventional mathematics instruction among Grade 8 students learning the Pythagorean theorem. By focusing on changes in overall geometrical-thinking performance, the study seeks to extend existing mathematics education literature through empirical evidence concerning the association between experiential learning and students' geometric reasoning while acknowledging the methodological limitations inherent in quasi-experimental classroom research.

METHOD

Research Design

The study was conducted at SMP Negeri 42 Batam, Indonesia, during the odd semester of the 2024/2025 academic year. The participants comprised 50 eighth-grade students who were organized into an experimental class and a control class, with 25 students in each class. The experimental class received mathematics instruction based on experiential learning, while the control class received conventional mathematics instruction. The study focused on geometrical thinking in the context of the Pythagorean theorem.

The participating students were drawn from the Grade 8 population at the research site. The use of existing classes reflects the school-based setting of the quasi-experimental study rather than individual random assignment. Accordingly, the findings are interpreted within the context of the participating students and the instructional setting.

Population and the methods of sampling

The population consisted of Grade 8 students enrolled at SMP Negeri 42 Batam during the odd semester of the 2024/2025 academic year. Participants were selected using purposive sampling based on the initial ability characteristics of the students and the suitability of the research setting for implementing the instructional activities. A total of 50 students were included in the study, consisting of 25 students in the experimental group and 25 students in the control group.

The selection of participants was conducted within the existing school-based class arrangement. The two groups were subsequently exposed to different instructional conditions, with the experimental group receiving experiential learning and the control group receiving conventional instruction. Because the study used purposive sampling and existing class arrangements, the allocation should not be interpreted as individual random assignment. The pretest was administered to both groups before the instructional intervention to document their initial geometrical-thinking performance.

Instrumentation

The principal instrument used in this study was a written essay test designed to assess students' geometrical thinking in geometry learning. The test consisted of four essay items, with each item scored from 0 to 4, resulting in a maximum raw score of 16. The scores were subsequently converted to a 0–100 scale using the formula $Score = (RawScore/16) \times 100$. The instrument assessed four aspects of geometrical thinking: visual-spatial reasoning, recognition of geometric properties, applied problem solving, and concept application. The items required students to analyze the relationship between the areas of geometric figures, construct and examine a right triangle using the Pythagorean theorem, solve a contextual problem involving the height of a kite, and determine the diagonal length of a rectangular object.

The four indicators were operationalized from the conceptualization of geometrical thinking used in this study. Visual-spatial reasoning represents students' ability to interpret and reason from geometric representations; recognition of geometric properties represents the identification and examination of characteristics and relationships among geometric elements; applied problem solving represents the use of geometric relationships to solve contextual problems; and concept

application represents the ability to apply geometric concepts to problem situations. These indicators were therefore used to provide overall coverage of geometrical thinking rather than to represent separate dependent outcomes. Each item was assessed using an analytic scoring rubric ranging from 0 to 4. The rubric considered the correctness of students' reasoning, use of geometric concepts, completeness of calculation procedures, and accuracy of the final answer. The maximum total score was 16.

Before being administered to the research participants, the instrument was tested on a limited group of 11 respondents. Item validity was examined using the Pearson correlation between each item score and the total score. The item–total correlations ranged from .726 to .943, with all correlations statistically significant. The reliability analysis produced a Cronbach's alpha of .863 for the four items, indicating satisfactory internal consistency. Additional item analysis showed discrimination indices ranging from .50 to .75, categorized as good to very good. The difficulty indices ranged from .55 to .68, with all four items classified as having moderate difficulty. These results supported the use of the four-item essay instrument in the main study. An observation sheet was used as a complementary instrument to document classroom learning activities. The observation included students' discussion of geometric concepts, participation in group roles, presentation of discussion results, and formulation of geometric conclusions. The observation data were used to document the instructional process and were not treated as a separate quantitative outcome measure.

Procedures and Time Frame

The study was implemented in three meetings during the odd semester of the 2024/2025 academic year. The first meeting was allocated 2 × 40 minutes and consisted of the pretest and an initial introduction to the learning material. The pretest was completed individually by students in both groups for 45 minutes. In the experimental class, the initial learning activity introduced the Pythagorean theorem through a visual problem involving a right triangle and the areas of squares constructed on its sides. Students were encouraged to identify relationships among the areas before the teacher introduced the formal expression of the theorem. This activity provided an initial concrete experience from which students could examine and discuss the underlying geometric relationship. In the control class, the corresponding introductory activity was conducted through direct teacher explanation of the Pythagorean theorem, including identification of the hypotenuse and worked examples.

The second meeting, also allocated 2 × 40 minutes, constituted the main instructional intervention. In the experimental class, students participated in a structured experiential-learning sequence involving an origami-based activity, differentiated worksheets, individual exploration, heterogeneous group discussion, presentation, and reflection. Students first worked individually before discussing their solutions in heterogeneous groups based on their pretest performance. The teacher provided differentiated guidance during the activities. The instructional sequence was designed to connect concrete experience with reflection, conceptual development, and application of the Pythagorean theorem. The control class received conventional mathematics instruction during the second meeting. The instructional sequence consisted of teacher explanation, worked examples involving the Pythagorean theorem, question-and-answer activities, individual exercises, and discussion of the answers. Students used the same general learning materials provided by the school, including the textbook/LKPD and worksheet. Thus, the principal distinction between the two conditions was the instructional sequence used to engage students with the mathematical content.

The third meeting was allocated 1 × 40 minutes and was used for the posttest. Both groups completed the same test individually under classroom conditions. The posttest used the same four items as the pretest. The complete research sequence therefore covered three meetings, while the main treatment was implemented during one 80-minute instructional session. An observation sheet

was used during the instructional activities to document discussion of geometric concepts, group roles, presentation of solutions, and formulation of conclusions. These observations were used to describe the implementation of classroom activities and were not converted into a quantitative implementation-fidelity score.

Ethical Procedures

The study was conducted with permission from the participating school and in accordance with principles of voluntary participation, confidentiality, and responsible management of research data. Before data collection, the purpose and general procedures of the study were explained to the participants. Participation was voluntary, and students were informed that their participation and responses would not affect their academic standing. The identities of individual students were kept confidential and were not reported in the manuscript. The collected data were used solely for research purposes and were handled to protect participants' privacy. The instructional activities were conducted within the regular school setting and involved learning activities consistent with the instructional procedures described in the study.

Data Analysis

Data analysis was conducted using the pretest and posttest scores from the experimental and control groups. Each test item was scored from 0 to 4, resulting in a maximum raw score of 16. Raw scores were converted to a 0–100 scale for reporting purposes using the formula $Score = (RawScore/16) \times 100$. Descriptive statistics, including means and standard deviations, were calculated for pretest, posttest, and change scores. Before the main inferential analysis, the distribution of the scores and the homogeneity of variance were examined. Normality was assessed using the Shapiro–Wilk test, while equality of variance was assessed using Levene's test. Because the experimental-group change scores showed a slight departure from normality, a nonparametric sensitivity analysis was also conducted using the Mann–Whitney U test. These checks were used to assess the robustness of the between-group comparison rather than to determine the instructional effect independently.

The baseline comparability of the two groups was examined using an independent-samples t-test on pretest scores. Because the study used existing school-based classes rather than individual random assignment, any baseline difference was explicitly considered when interpreting the outcomes. The primary analysis examined whether the amount of improvement from pretest to posttest differed between the two groups. For each student, a change score was calculated as posttest score minus pretest score. The mean change scores were compared between the experimental and control groups using an independent-samples t-test. The standardized magnitude of the between-group difference was evaluated using Cohen's d, with a 95% confidence interval where applicable.

Because the groups differed in baseline performance, a supplementary regression analysis was conducted with posttest performance as the dependent variable, instructional group and pretest performance as predictors, and the Group × Pretest interaction included in the model. The interaction term was examined to determine whether the relationship between baseline and posttest performance differed between the two groups. Because the interaction was statistically significant, the regression model was interpreted as supplementary evidence rather than as a conventional equal-slopes ANCOVA estimate of a single adjusted treatment effect. Paired-samples t-tests were additionally conducted to describe pretest–posttest changes within each group. These tests were treated as supplementary because a statistically significant within-group change does not by itself establish that one instructional condition produced greater improvement than another. Normalized gain (N-Gain) was calculated as a supplementary descriptive measure using the formula $g = (posttest - pretest)/(100 - pretest)$. N-Gain was used to describe the magnitude of improvement within each group and was not treated as the primary basis for comparing instructional conditions.

Statistical significance was evaluated at α = .05. Exact p-values were reported when p ≥ .001, whereas values below .001 were reported as p < .001 rather than p = .000.

RESULTS AND DISCUSSION

Results

The descriptive results showed different patterns of geometrical-thinking performance between the experimental and control groups. Based on the raw scores and the specified conversion procedure, the experimental group obtained a pretest mean of 36.25 (SD = 11.41), whereas the control group obtained a pretest mean of 28.50 (SD = 11.42). Following the instructional activities, the experimental group obtained a posttest mean of 66.00 (SD = 19.10), while the control group obtained a posttest mean of 35.00 (SD = 24.54). The experimental group therefore showed a larger increase in performance than the control group. The individual records indicate a substantial upward shift in the experimental group, whereas improvement in the control group was more limited and heterogeneous.

An initial comparison of the pretest scores indicated a statistically significant difference between the two groups, t (48) = 2.40, p = .020. The experimental group therefore started with a higher level of geometrical-thinking performance than the control group. Because of this baseline difference, the posttest means were not interpreted as the sole evidence of an instructional effect. Instead, the primary comparison focused on the difference in change between the two groups.

Table 1. Pretest and Posttest Descriptive Statistics

Group	Pretest Mean ± SD	Posttest Mean ± SD	Mean Change
Experimental	36.25 ± 11.41	66.00 ± 19.10	29.75
Control	28.50 ± 11.42	35.00 ± 24.54	6.50

The experimental group increased by 29.75 points, compared with 6.50 points in the control group. Thus, the difference in mean improvement between the groups was 23.25 points. This descriptive pattern indicates substantially greater improvement in the experimental condition. The between-group comparison of change scores showed a statistically significant difference in improvement between the two groups, t(48) = 3.97, p < .001. The standardized difference in change was large (Cohen's d = 1.12), indicating a substantial difference in improvement between the two instructional conditions.

Table 2. Between-Group Comparison of Change Scores

Group	Mean Change	SD of Change	*t*	df	*p*	Cohen's *d*
Experimental	29.75	22.55	3.97	48	< .001	1.12
Control	6.50	18.62	—	—	—	—

The within-group analyses were examined as supplementary evidence. The experimental group showed a statistically significant increase from pretest to posttest, t(24) = −6.60, p < .001. The control group did not show a statistically significant change, t(24) = −1.75, p = .094. The negative signs of the t-values resulted from calculating the paired difference as pretest minus posttest and therefore do not indicate a negative improvement.

Table 3. Paired-Samples t-Test Results

Group	Mean Difference (Pretest – Posttest)	SD	*t*	df	*p*
Experimental	−29.75	22.55	−6.60	24	< .001
Control	−6.50	18.62	−1.75	24	.094

The N-Gain analysis provided a supplementary description of the magnitude of individual improvement. The mean N-Gain was 0.445 for the experimental group and 0.107 for the control group. Based on the classification used in the study, these values correspond to moderate and low

improvement, respectively. The N-Gain results were consistent with the change-score analysis, although they were not treated as the primary inferential evidence because the two groups differed in their initial performance.

Table 4. Supplementary N-Gain Results

Group	Mean N-Gain	Category
Experimental	0.445	Moderate
Control	0.107	Low

Because the groups differed at baseline, a supplementary regression analysis was conducted with posttest performance as the outcome and instructional group and pretest performance as predictors. The model was statistically significant, $F(2,47) = 17.85$, $p < .001$, $R^2 = .432$. The coefficient for instructional group was statistically significant, $B = 4.07$, $SE = 0.99$, $t(47) = 4.12$, $p < .001$, 95% CI [2.09, 6.06]. The coefficients are reported on the raw 0–16 score scale. However, the Group × Pretest interaction was statistically significant, $F(1,46) = 10.33$, $p = .002$, indicating that the relationship between pretest and posttest performance differed between the two groups. Therefore, the regression analysis was interpreted as supplementary evidence rather than as a conventional equal-slopes ANCOVA estimate of a single adjusted treatment effect.

However, the Group × Pretest interaction was statistically significant, $F(1,46) = 10.33$, $p = .002$. This finding indicates that the relationship between initial and posttest performance differed between the two instructional groups. Consequently, a conventional equal-slopes ANCOVA was not treated as the primary analysis. The difference-in-change analysis was therefore retained as the principal comparative analysis, while the baseline-adjusted regression was used as supplementary evidence concerning the initial group difference.

Table 5. Baseline-Adjusted Regression Analysis

Predictor	B (Raw Score)	SE	*t*	*p*	95% CI
Intercept	2.34	1.36	1.72	.092	−0.40, 5.08
Experimental group	4.07	0.99	4.12	< .001	2.09, 6.06
Pretest	0.71	0.26	2.74	.009	0.19, 1.24

Overall, the results indicate that the experiential-learning condition was associated with greater improvement in students' overall geometrical-thinking performance than the conventional-learning condition. The primary evidence comes from the statistically significant difference in change scores and the large standardized difference, while the paired-samples and N-Gain analyses provide supplementary evidence. Given the quasi-experimental design and the significant baseline difference between groups, these findings should be interpreted as evidence of an association between the instructional condition and greater improvement rather than as definitive proof of a causal effect.

Discussion

The findings indicate that the experiential-learning condition was associated with greater improvement in students' overall geometrical-thinking performance than the conventional-learning condition. This interpretation is based primarily on the difference in pretest-to-posttest change between the two groups rather than on the posttest means alone. The experimental group began with higher initial performance, but it also exhibited a substantially larger increase during the instructional period. The between-group comparison of change therefore provides stronger evidence for the observed difference than separate within-group significance tests. Given the quasi-experimental design and the baseline imbalance, the finding should be interpreted as an association between the instructional condition and greater improvement rather than as definitive evidence of a causal effect.

The pattern of improvement can be interpreted in relation to the structure of the experiential-learning activities implemented in the experimental class. The instructional sequence

moved students from direct experience toward reflection, conceptualization, and application. In the first stage, students were introduced to the Pythagorean relationship through a visual situation involving a right triangle and squares constructed on its sides. Rather than receiving the formula solely as an established rule, students were initially encouraged to consider the relationship among the areas represented in the activity. This provided a concrete starting point from which the mathematical relationship could be explored.

The subsequent learning activities extended this process through reflection and collaborative examination. During the main intervention, students worked with differentiated worksheets and an origami-based activity, first completing tasks individually and then discussing their findings within heterogeneous groups. Students were also asked to present selected solutions and reflect on what they had learned. These activities correspond to the reflective dimension of experiential learning because students were not only exposed to a mathematical procedure but were required to examine observations, compare solutions, explain ideas, and reconsider their understanding through interaction with peers. Pasted markdown

The transition from experience and reflection to conceptualization is particularly relevant to geometry learning. Geometrical thinking requires students to move beyond recognizing visual forms toward identifying properties, relationships, and mathematical explanations. In the present intervention, teacher guidance was used to help students organize observations into mathematical concepts and procedures related to the Pythagorean theorem. The final phase required students to apply the resulting understanding to problems in different situations. Thus, the instructional sequence provided opportunities to connect concrete representations, reflection, mathematical formulation, and application rather than presenting the theorem exclusively through direct explanation. Pasted markdown

This interpretation is consistent with previous research on experiential learning in mathematics. Supriani et al. (2019) demonstrated the use of experiential learning to support students' mathematical justification, while Supriani & Sholahudin (2019) applied the approach to students' ability to formulate mathematical conjectures. Uyen et al. (2022) further examined experiential learning in arithmetic and geometry, and Buakieow & Kijkuakul (2023) reported its application to mathematical connections. More recently, Žakelj et al. (2024) examined active and experiential learning among eighth-grade students. Taken together, these studies provide converging evidence that experience-oriented learning can support mathematical learning through activities that connect experience, reflection, conceptualization, and application. The present study extends this evidence by focusing specifically on overall geometrical-thinking performance among Grade 8 students rather than on mathematical achievement or a single mathematical competency.

The finding also provides a conceptual connection with the Van Hiele perspective on geometrical thinking. The Van Hiele framework emphasizes that students' geometric understanding develops through increasingly organized ways of recognizing figures, properties, relationships, and reasoning (Naufal et al., 2021; van Hiele, 1986). Previous empirical studies have reported variation in students' geometric thinking levels and difficulties in developing more sophisticated geometric reasoning (Al Afgoni et al., 2020; Putri et al., 2024; Susanto & Mahmudi, 2021). Research specifically examining the Pythagorean theorem has likewise demonstrated the relevance of Van Hiele theory for understanding students' geometrical thinking (Arnita et al., 2024). The present study did not directly measure students' movement across specific Van Hiele levels; therefore, such progression cannot be claimed from the data. Nevertheless, the experiential-learning sequence provided opportunities for students to examine visual representations, identify geometric relationships, formulate mathematical explanations, and apply those relationships to problems. Pasted markdown

The difference between the two instructional conditions may also be related to the contrast in classroom learning processes documented in the instructional plans. The experimental class

engaged in individual exploration followed by heterogeneous group discussion, presentation, reflection, and differentiated teacher support. In contrast, the control class received teacher explanations, worked examples, question-and-answer activities, and individual practice. This contrast provides a plausible instructional explanation for the observed difference because students in the experimental condition had more opportunities to externalize their reasoning, compare interpretations, and connect representations with mathematical procedures. However, because these classroom processes were not separately quantified as mediating variables, the study cannot establish which particular process accounted for the difference. Pasted markdown

The findings should also be interpreted cautiously with respect to the specific dimensions of geometrical thinking assessed by the instrument. The test included visual-spatial reasoning, recognition of geometric properties, applied problem solving, and concept application. These indicators provide conceptual coverage of the assessment, but the analysis treated the test as an overall measure of geometrical thinking. Consequently, the findings should not be interpreted as demonstrating that experiential learning independently improved each dimension. Dimension-specific conclusions would require separate analyses with sufficient item coverage for each dimension. Pasted markdown

The within-group findings provide supporting rather than decisive evidence for this interpretation. The experimental group showed a statistically significant pretest-to-posttest increase, whereas the corresponding change in the control group was not statistically significant. However, the significance of a within-group change does not by itself establish superiority of one instructional condition. The more informative evidence is the difference in change between the two groups. This distinction is important because separate paired-samples tests should not be interpreted independently as evidence of a treatment effect. Pasted markdown

From a pedagogical perspective, the findings suggest that experiential learning may be useful when geometry instruction requires students to connect representations, observations, mathematical relationships, and applications. The experimental lesson did not simply replace teacher explanation with activity; rather, activities were organized into a sequence in which students encountered a geometric relationship, examined it through guided activities, discussed their interpretations, formulated the underlying concept, and applied it to problems. Thus, the potential value of experiential learning lies not merely in providing hands-on activities but in connecting those activities with reflection, conceptual development, and subsequent mathematical application. Pasted markdown

Several limitations should be considered when interpreting these findings. The study involved 50 Grade 8 students from one school and used existing school-based groups rather than individual random assignment. The groups also differed significantly in pretest performance, limiting the strength of causal interpretation despite the additional change-score and baseline-adjusted analyses. The intervention was conducted over a short instructional period, and the assessment consisted of four essay items administered in the same form at pretest and posttest. The repeated use of the same items may introduce practice or familiarity effects. Finally, the study focused on the Pythagorean theorem and therefore does not establish whether the same pattern would occur across other geometry topics. Pasted markdown

Future research should involve larger samples from multiple schools and, where feasible, stronger allocation procedures. Longer interventions and delayed posttests could help determine whether improvement is sustained beyond the immediate posttest. Parallel assessment forms could also reduce potential practice effects. In addition, future studies could analyze geometrical-thinking dimensions separately and examine whether specific components of the experiential cycle—such as concrete manipulation, reflection, collaborative discussion, or active application—contribute differently to students' geometric reasoning. Such research would provide a stronger basis for

explaining the mechanisms through which experiential learning may support geometrical thinking. Pasted markdown.

Implications

The findings suggest that experiential learning can be considered as an instructional option for geometry lessons that require students to connect geometric representations, relationships, conceptual explanations, and applications. In the present study, the approach was implemented through concrete activities, individual exploration, group discussion, presentation, reflection, and subsequent application of the Pythagorean theorem. From a pedagogical perspective, the findings suggest that experience-based instruction may be more useful when concrete activities are deliberately connected to reflection and mathematical conceptualization rather than being used as isolated hands-on activities. Teachers implementing a similar approach should therefore provide opportunities for students to examine geometric relationships, explain their reasoning, discuss alternative solutions, and apply the resulting concepts to problems. The implications should be interpreted within the scope of the present assessment. The study measured overall geometrical-thinking performance using four indicators, but the indicators were not analyzed as separate outcomes. Therefore, the findings should not be interpreted as evidence that experiential learning independently improves each specific dimension of geometrical thinking.

Limitations and Suggestions for Future Research

Several limitations should be considered when interpreting the findings. First, the study involved only 50 Grade 8 students from a single school and used existing school-based classes rather than individual random assignment. Therefore, the findings may not be generalizable to students in other schools, regions, or educational contexts. Second, the experimental and control groups differed significantly in their pretest performance. Although the analysis compared pretest-to-posttest change and included a supplementary baseline-adjusted regression model, the initial imbalance limits the strength of causal interpretation. Third, the intervention was implemented over a short period. The main instructional treatment occurred during one 80-minute session within a three-meeting research sequence. Consequently, the findings provide evidence of short-term improvement and do not establish whether the observed gains would be sustained over a longer period.

Fourth, the assessment consisted of only four essay items covering the selected indicators of geometrical thinking. Although the instrument demonstrated satisfactory item validity and internal consistency, the limited number of items may restrict the breadth of geometrical-thinking measurement. Fifth, the same test items were used for the pretest and posttest. Although this procedure ensured consistency of measurement, repeated exposure to the same items may have introduced familiarity or practice effects that cannot be completely separated from the instructional effect. Finally, the study focused on geometrical thinking in the context of the Pythagorean theorem. The findings therefore should not be generalized to all geometry topics without further evidence. In addition, the study did not separately analyze the four dimensions of geometrical thinking or quantify the contribution of individual components of the experiential-learning cycle.

CONCLUSION

This study indicates that experiential learning was associated with greater improvement in overall geometrical-thinking performance among Grade 8 students than conventional mathematics instruction. The difference was reflected in the substantially greater pretest-to-posttest improvement observed in the experiential-learning group. The findings therefore suggest that an instructional sequence involving concrete experience, reflection, conceptual development, and active

application can provide a productive context for supporting students' geometrical thinking in learning the Pythagorean theorem.

The findings should nevertheless be interpreted within the limitations of the quasi-experimental design. The participants were drawn from existing classes at a single school, and the two groups differed in their initial geometrical-thinking performance. Therefore, the study does not establish definitive causal effects or demonstrate that experiential learning produces the same outcomes across other student populations or geometry topics. In addition, the intervention was implemented over a short instructional period and the same assessment form was used for the pretest and posttest.

The study contributes to mathematics education by providing empirical evidence concerning the association between an experience-oriented instructional sequence and improvement in overall geometrical thinking. Rather than attributing the observed improvement to a single instructional activity, the findings support the value of connecting concrete experience with reflection, mathematical conceptualization, and subsequent application. Future research should examine this approach with larger and more diverse samples, longer intervention periods, alternative assessment forms, and separate analyses of specific dimensions of geometrical thinking.

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AUTHOR CONTRIBUTIONS STATEMENT

Yani Supriani and Indri Lestari jointly contributed to conducting the research and preparing the manuscript. Both authors participated in completing the study and reviewed and approved the final manuscript.

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