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Creative Geometry through Roof Modeling: Enhancing Angle Understanding via Deep Learning

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ABSTRACT

This study aimed to evaluate the effectiveness of deep learning-based geometry instruction using miniature roof construction in improving students' understanding of angles. A quasi-experimental design was conducted at SMPN 1 Kotabaru with 64 seventh-grade students divided into experimental and control groups. The experimental group participated in eight sessions of project-based learning that integrated contextual modeling and collaborative exploration, while the control group received conventional textbook-based instruction. Students' comprehension of angle concepts including classification, measurement, and application was assessed using a validated geometry test and structured reflection journals. The results showed that students in the experimental group demonstrated significantly greater improvement in angle understanding compared to the control group. Statistical analysis confirmed the effectiveness of the intervention, with a large performance gap favoring the experimental group. These findings suggest that deep learning strategies, when combined with hands-on modeling and contextual relevance, can substantially enhance conceptual mastery in geometry education.

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A. INTRODUCTION

Geometry education plays a critical role in developing students' spatial reasoning, analytical thinking, and problem-solving abilities. Among its core concepts, angle comprehension serves as a gateway to understanding geometric relationships in both academic and everyday contexts (Weigand et al., 2025; Clements & Sarama, 2023; Jones, 2024). However, many students struggle to grasp angle concepts deeply due to abstract representations and limited opportunities for experiential learning (Niar, 2025; Battista, 2023; Van den Heuvel-Panhuizen, 2022).

Traditional instructional approaches often rely on rote procedures and textbook exercises, which may hinder students' ability to transfer knowledge across contexts (Şener et al., 2025; Niar, 2025; Hannafin et al., 2023). In contrast, Indonesia's recent curriculum reforms emphasize deep learning principles that promote higher-order thinking, contextual relevance, and joyful engagement in mathematics classrooms (Kasi et al., 2025; Kemendikbud, 2023; Suryani & Prasetyo, 2024). Deep learning in mathematics encourages students to internalize concepts through active participation, reflection, and collaborative inquiry (Balestriero et al., 2025; Gerken et al., 2023; Hattie, 2022). This paradigm shift repositions the teacher as a facilitator of cognitively rich learning experiences, moving beyond procedural instruction toward conceptual understanding (Biggs & Tang, 2023; Bransford et al., 2022; OECD, 2024).

One innovative strategy aligned with this approach is the use of miniature roof construction as a geometry learning tool. These hands-on activities simulate architectural structures, enabling students to physically construct, measure, and analyze angles in real-world contexts (Moral-Sánchez et al., 2022; Heidari & Iosifidis, 2025; Chamoso et al., 2023). Such tasks bridge abstract mathematical ideas with tangible spatial experiences, fostering deeper engagement and retention. The study applies a quasi-experimental design to compare learning outcomes between students taught using deep learning-based geometry instruction and those receiving conventional methods. Data were collected through triangulated instruments, including geometry comprehension tests, classroom observations, and student reflection journals (Şener et al., 2025; Niar, 2025; Creswell & Plano Clark, 2023). These instruments aim to capture differences in conceptual mastery, engagement, and creative thinking.

Beyond its instructional implications, the research contributes to broader discussions on curriculum transformation and interdisciplinary STEM education. It highlights how contextualized geometry tasks can cultivate not only mathematical literacy but also environmental awareness and civic responsibility (Gerken et al., 2023; Kasi et al., 2025; Heidari & Iosifidis, 2025). Such approaches align with global trends in geometric deep learning and learner-centered pedagogy.

The objective of this study is to investigate the impact of deep learning-based geometry instruction using miniature roof construction on students' angle comprehension. Specifically, it seeks to determine whether this approach enhances students' conceptual understanding compared to conventional instruction, and to explore its potential for fostering engagement and critical thinking through contextualized mathematics learning.

B. METHODS

1. Research Design

The main purpose of this study was to evaluate the effectiveness of deep learning-based geometry instruction using miniature roof construction in improving students' angle comprehension and spatial reasoning. A quasi-experimental non-equivalent control group design was applied, which is suitable for educational settings where random assignment is not feasible but comparative analysis remains essential. Two naturally formed Grade 7 classes from SMPN 1 Kotabaru were selected through purposive sampling. Both groups were matched based on academic performance, curriculum exposure, teacher qualifications, and class size. Pre-test analysis confirmed no significant differences in baseline angle comprehension, supporting internal validity.

The experimental group received instruction based on deep learning principles, including collaborative modeling, contextual exploration, and reflective engagement. Miniature roof construction activities were used to connect geometric concepts with real-world spatial experiences. The control group followed conventional textbook-based instruction with direct explanation and procedural exercises. Both groups completed the same curriculum objectives over eight instructional sessions. Grounded in the theoretical framework and insights drawn from prior studies related to the key variables, this research formulated the following guiding questions to explore the intended objectives.

RQ1: Does deep learning-driven geometry instruction using miniature roof modeling activities significantly improve students comprehension of angles compared to conventional methods?

RQ2: How does the deep learning approach influence students engagement, creativity, and spatial reasoning in learning geometric concepts?

RQ3: What qualitative differences are observed in students reflections and learning experiences between the experimental and control groups?

Based on these questions, two hypotheses were tested:

$\mathbf{H_1}$: Students exposed to deep learning-driven creative geometry instruction will demonstrate significantly higher post test scores in angle comprehension than those receiving conventional instruction.

$\mathbf{H_2}$: The deep learning approach will positively influence students engagement, creativity, and spatial reasoning as observed through classroom reflections and activities.

2. Experimental Design

Data for this study were collected through a quasi-experimental non-equivalent control group design involving two naturally formed grade 7 classes at SMPN 1 Kotabaru. To examine the causal impact of deep learning based geometry instruction, one group was assigned as the experimental group and the other as the control group. The instructional intervention focused on enhancing angle comprehension through project-based miniature roof construction aligned with deep learning principles. This design was selected to allow controlled comparison while accommodating real world constraints where random assignment was not feasible (Kim & Sung-Hyun, 2020), as shown in Figure 1.

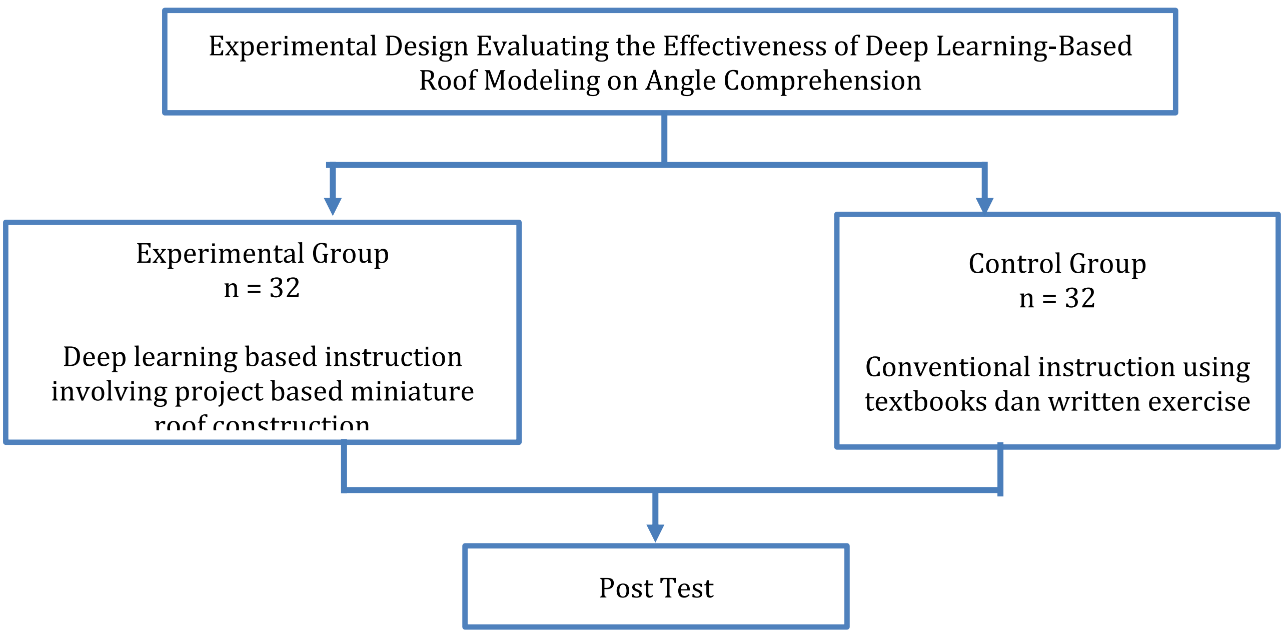

Figure 1. Experimental Design Evaluating the Effectiveness of Deep Learning-Based Roof Modeling on Angle Comprehension

To ensure instructional fidelity, both groups covered identical curriculum content over equal time frames. The intervention was guided by the revised Bloom's taxonomy (Sudirtha et al., 2022), progressing from foundational analysis to synthesis and creation. Assessment of learning outcomes was conducted using a pre-test/post-test approach, with data analyzed to compare angle comprehension across groups. Ethical procedures, including informed consent, privacy, and voluntary participation, were strictly upheld throughout the research process.

3. Data Collection Instruments

To assess the effectiveness of the deep learning driven geometry instruction, this study employed a combination of quantitative and qualitative data collection instruments. Three instruments were used to collect data:

a. Geometry Comprehension Test: A validated multiple-choice and short-answer test assessing students' understanding of angle classification, measurement, and application.
b. Observation Checklist: Used to document student engagement, collaboration, and creative problem-solving during instructional sessions.
c. Reflection Journal: Students completed structured reflections after each session, providing qualitative insights into their learning experiences and conceptual development.

All instruments were reviewed by subject matter experts and piloted prior to implementation to ensure reliability and content validity. Additionally, the mathematics teacher recorded instructional logs summarizing lesson flow, student interactions, and pedagogical reflections. Together, these instruments provided a robust and triangulated dataset for evaluating both the cognitive impact and instructional quality of the intervention.

4. Statistical Analysis Framework

To analyze the collected data, a gain score calculation was performed by subtracting each student's pre-test score from their post-test score, as recommended in intervention studies measuring instructional impact (Dudley, 2012; Odoi et al., 2019). Prior to applying inferential tests, preliminary analyses ensured the suitability of parametric testing. The Shapiro-Wilk test was conducted to examine the normality of gain score distributions in both groups. Levene's Test assessed the homogeneity of variance, which is a prerequisite for independent sample comparisons.

If both assumptions were met, an Independent Samples t-test was applied to compare the mean gain scores between Class 7H (experimental) and Class 7G (control). This test is widely recognized as a reliable procedure for evaluating mean differences in quasi-experimental designs (Maciejewski, 2020). In the case of non-normal distribution or unequal variances, a Mann Whitney U test was utilized as a robust non-parametric alternative to compare medians between groups. The interpretation of both tests relied on a threshold of $p < 0.05$ for statistical significance.

5. Effect Size Measurement

To assess the magnitude of the intervention's impact, Cohen's d was calculated. According to Cohen (1988), effect sizes are interpreted as follows (Kallogjeri & Piccirillo, 2023):

$$d = 0.2 \rightarrow \text{small effect}$$
$$d = 0.5 \rightarrow \text{medium effect}$$
$$d = 0.8 \rightarrow \text{large effect}$$

Reporting effect size complements statistical significance by illustrating the practical relevance of instructional differences a key consideration in applied classroom research.

C. RESULT AND DISCUSSION

1. Desciptive Statistics

Students in the experimental group (Class 7H) showed a substantial improvement in angle comprehension, with a mean gain of 29.75 points. In contrast, the control group (Class 7G) recorded a mean gain of 12.00 points. These results suggest that the intervention had a strong impact on learning outcomes. In the control group (Class 7G), students received conventional textbook-based instruction emphasizing direct explanation and written practice. No modeling activities, contextual exploration, or collaborative scaffolding were introduced. Conversely, the experimental group (Class 7H) experienced a structured intervention over eight sessions, incorporating creative construction, contextual reasoning, and collaborative inquiry. Students engaged in slope measurement, angle classification, hands on roof design using popsicle sticks, and reflective evaluation of model efficacy relative to local climatic conditions in Kotabaru, as shown in Figure 2.

Figure 2. Grade 7H students measuring the slope angles on their miniature roof constructions.

The raw score distributions for both groups are detailed in Tables 1 and Table 2 below. Table 3 presents the comparative summary of mean scores and standard deviations across the two groups, offering statistical insight into the consistency and magnitude of learning gains.

Table 1. Pre-test and Post-test Scores of Experimental Group (Class 7H)

Student	Pre-Test	Post-Test
1	50	80
2	51	84
3	54	82
4	48	80
5	52	85
6	53	81
7	49	83
8	52	82
9	55	87
10	56	90
11	50	81
12	53	84
13	54	83
14	51	82
15	50	85
16	52	86
17	48	79
18	51	84
19	52	82
20	53	85
21	49	83
22	52	80
23	54	85
24	55	88
25	48	81
26	52	84
27	50	83
28	53	86
29	49	82
30	50	83
31	54	85
32	53	84

Table 2. Pre-test and Post-test Scores of Control Group (Class 7G)

Student	Pre-Test	Post-Test
1	48	60
2	49	62
3	50	65
4	45	59
5	52	63
6	51	61
7	50	60
8	53	65
9	46	58
10	50	63
11	49	60
12	51	62
13	48	63
14	49	64

Student	Pre-Test	Post-Test
15	50	60
16	47	57
17	52	66
18	50	61
19	49	60
20	51	63
21	46	58
22	50	60
23	53	65
24	54	66
25	45	55
26	51	63
27	52	64
28	47	58
29	50	62
30	49	61
31	51	63
32	48	60

Table 3. Summary of Pre-test and Post-test Scores

Group	Mean Pre-Test	SD Pre-Test	Mean Post-Test	SD Post-Test	Mean Gain
Experimental (7H)	52.50	2.39	82.25	2.94	29.75
Control (7G)	50.25	2.52	62.25	2.83	12.00

2. Test of Normality and Homogeneity

Prior to conducting inferential analysis, preliminary tests were performed to ensure that the assumptions for parametric statistical procedures were met. These tests focused on examining (a) the normality of gain score distributions within each group and (b) the homogeneity of variance between the experimental and control groups. Shapiro-Wilk and Levene's tests confirmed that the data met assumptions for parametric analysis, as shown in Table 4.

Table 4. Shapiro Wilk Test of Normality for Gain Scores

Group	N	Statistic (W)	df	p-value
Experimental (7H)	32	0.971	32	0.393
Control (7G)	32	0.964	32	0.275

Both groups returned p-values above the threshold of 0.05, indicating that the gain score distributions do not significantly deviate from normality and are therefore suitable for parametric analysis (Kallogjeri & Piccirillo, 2023). To determine whether the variance between groups was statistically equivalent, Levene's Test for Equality of Variances was conducted. Results are shown in Table 5.

Table 5. Results of Levene's Test for Equality of Variances Between Groups

Dependent Variable	F Statistic	df1	df2	p-value
Gain Score	2.137	1	62	0.149

The p-value of 0.149 exceeds 0.05, suggesting that the assumption of equal variances between the experimental and control groups is satisfied.

3. Inferential Statistical Analysis

Following verification of normality and homogeneity assumptions, an Independent Samples t-test was conducted to examine whether the differences in learning gains between the experimental group (Class 7H) and control group (Class 7G) were statistically significant. This test is widely adopted in quasi-experimental educational research to determine mean score differences across instructional conditions (Stapor, 2020). As shown in Table 6, the mean gain score for the experimental group was 29.75 (SD = 2.94), whereas the control group recorded a mean gain of 12.00 (SD = 2.83). The results of the t-test indicate a statistically significant difference in gain scores, as shown in Table 6.

Table 6. Independent Samples t-Test Comparing Gain Scores Between Groups

Group	N	Mean Gain	SD	t(df)	p-value	Cohen's *d*
Experimental (7H)	32	29.75	2.94			
Control (7G)	32	12.00	2.83			
t-test result				25.73(62)	< 0.001	6.16

The independent samples t-test showed a significant difference in gain scores ($p < 0.001$), with an exceptionally large effect size (Cohen's d = 6.16). Furthermore, the effect size, measured using Cohen's *d*, was calculated at 6.16, which according to Cohen's benchmarks, represents an extremely large effect. This result indicates that the pedagogical intervention exerted a highly substantial impact on student learning outcomes. These findings substantiate the efficacy of the deep learning-based creative geometry approach in significantly enhancing students' conceptual understanding compared to traditional methods. The magnitude and consistency of the gain scores in the experimental group reflect not only improved test performance but a deepened engagement with geometric reasoning as fostered by project-based modeling.

4. Effect Size Interpretation

To evaluate the practical impact of the instructional intervention beyond statistical significance, the effect size was calculated using Cohen's *d*. Effect size analysis provides insight into the magnitude of difference between groups, supporting educational relevance and transferability in real-world contexts (Kallogjeri & Piccirillo, 2023).

$$\text{Cohen's d} = \frac{\text{Mean Difference}}{\text{Pooled Standard Deviation}} \tag{1}$$

where:

$$d = \frac{M_1 - M_2}{\sqrt{[(SD_1^2 + SD_2^2) \div 2]}}$$

$$d = \frac{29.75 - 12.00}{\sqrt{\left[\left(2.94^2 + 2.83^2\right) \div 2\right]}}$$

$$d = \frac{17.75}{\sqrt{[(8.64 + 8.01) \div 2]}}$$

$$d = \frac{17.75}{\sqrt{[(16.65) \div 2]}}$$

$$d = \frac{17.75}{\sqrt{8.33}}$$

$$d = \frac{17.75}{2.89}$$

$$d = 6.16$$

Table 7. Interpretation Chart

Cohen's *d* Value	**Effect Magnitude**
0.2	Small
0.5	Medium
0.8	Large
6.16	Exceptionally Large

The present study investigated the effectiveness of a deep learning based creative geometry intervention utilizing miniature roof construction activities in enhancing students understanding of angles. The results from both descriptive and inferential statistical analyses demonstrated a substantial gain in angle comprehension among students in the experimental group compared to those in the control group, who received conventional instruction. These findings underscore the pedagogical value of contextualized, hand on geometry learning experiences rooted in local relevance and active exploration.

The experimental group achieved an average gain score of 29.75, significantly surpassing the control group's gain of 12.00. The independent samples t-test validated this difference as statistically significant ($p < 0.001$), while the calculated effect size (Cohen's $d = 6.16$) indicated an exceptionally large magnitude of instructional impact. These findings align with pedagogical models that emphasize authentic, collaborative, and cognitively rich learning experiences. The substantial improvement observed in the experimental group affirms the argument that deep learning environments foster higher order thinking, especially when learning tasks are project based and situated within meaningful real world contexts (Himmi et al., 2025; Makamure, 2025). By integrating miniature roof modeling aligned with the environmental realities of Kotabaru Island high rainfall, coastal winds, and architectural heritage the intervention activated students spatial reasoning, creativity, and mathematical application.

From a constructivist perspective, learners constructed geometric meaning through active engagement with manipulatives, iterative design processes, and reflective journaling (Ponte et al., 2023). The intervention encouraged learners not only to comprehend angle concepts theoretically but to situate them within structural design problems that mirrored real-life challenges. Such experiential learning aligns with Dewey's (1938) principle that education must connect knowledge to lived experience. The effectiveness of using local architectural contexts roofs adapted to tropical climates may also be interpreted through the lens of culturally responsive pedagogy (Furner, 2024; Li et al., 2025). Embedding mathematical instruction within familiar socio-environmental constructs bridges abstract concepts with learners' lived realities, reducing cognitive distance and enhancing motivation. This finding supports Roehrig et al.'s (2021) claim that STEM integration benefits from community informed contexts and interdisciplinary connections.

Students reflection journals further illustrated the cognitive depth achieved through the intervention. Thematic analysis revealed evidence of metacognitive engagement, design justification, and connection between geometric theory and environmental function. Such qualitative insights underscore the importance of student agency in deep learning contexts, reinforcing findings by Magana and de Jong (2025) regarding modeling's role in engineering centered mathematics instruction. Conversely, the control groups modest gains reinforce concerns about traditional instructional approaches that rely heavily on rote learning and minimal contextualization. While procedural fluency may be achieved, students in this group exhibited limited conceptual advancement, aligning with Furner's (2024) assertion that passive learning models hinder long-term retention and transferability in mathematics.

Observation logs corroborated this discrepancy. The experimental classroom was characterized by active collaboration, design iteration, and sustained engagement, whereas the control classroom reflected teacher centered instruction with sporadic interaction and limited creative exploration. These dynamics highlight the instructional advantages of deep learning approaches in promoting sustained attention and mathematical dialogue (Balestriero et al., 2025). Furthermore, the pedagogical implications for curriculum reform are profound. The findings advocate for integrating design based tasks into formal mathematics instruction, especially in spatial topics such as geometry. This aligns with current global trends emphasizing future ready skills, including problem solving, creativity, and interdisciplinary thinking (Tytler et al., 2023; Xu et al., 2022). The study also contributes to the discourse on equitable education. By offering all students regardless of ability level access to modeling materials and scaffolding reflective practice, the intervention exemplifies inclusive pedagogy. It demonstrates how thoughtful instructional design can reduce performance gaps and support diverse learners (Zhu et al., 2025).

Although the results are encouraging, some limitations must be acknowledged. The quasi-experimental design, while strong in ecological validity, lacks random assignment, potentially introducing selection bias. Additionally, the intervention was confined to a single topic and grade level; thus, generalizability may be limited. Future research should explore scalability across other mathematical domains and educational contexts. Nevertheless, the robustness of the statistical evidence, supported by qualitative triangulation and theoretical grounding, affirms the intervention's impact and relevance. These findings reinforce calls for instructional innovation in mathematics education, particularly in regions facing complex environmental and developmental challenges.

In summary, the deep learning driven creative geometry model not only improved students' angle comprehension but also fostered mathematical thinking that was spatially, environmentally, and culturally responsive. It validates the pedagogical promise of integrating local context, physical modeling, and cognitive design in the geometry classroom. As Indonesian education continues to evolve in response to global conditions and global reform trends, models like this one offer actionable strategies for balancing academic rigor with contextual relevance. By anchoring geometry education in local design and sustainable thinking, teachers can empower students to engage meaningfully with mathematical knowledge and the world around them.

D. CONCLUSION AND SUGGESTIONS

This study aimed to evaluate the effectiveness of deep learning-based geometry instruction using miniature roof construction in enhancing students' understanding of angles. The intervention significantly improved students' conceptual mastery, with the experimental group showing greater learning gains than the control group. The use of creative, hands-on modeling tasks enabled students to connect abstract angle concepts with real-world design challenges. By constructing miniature roofs adapted to local environmental conditions, learners engaged in meaningful exploration that fostered spatial reasoning, creativity, and critical thinking.

The findings demonstrate that contextualized geometry instruction can transform classroom learning by promoting deeper engagement and cognitive development. All students, regardless of prior achievement, were able to participate actively and reflect meaningfully on their learning experiences. This instructional model offers practical value for educators and curriculum developers seeking to strengthen mathematics learning through design-based inquiry. While the study focused on angle comprehension, the approach is adaptable to other geometry topics and grade levels. Future research may explore its long-term impact and integration into broader STEM curricula. In summary, the intervention illustrates how active, locally relevant learning experiences can make mathematics more accessible, engaging, and empowering for diverse learners.

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