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The Effect of Problem-Based Learning Model Using Digital Snakes and Ladders on Primary School Pupils' Geometric Reasoning Skills

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Abstract: Primary school pupils' ability to reason geometrically remains a challenge in mathematics education, particularly regarding abstract concept angles, which require conceptual understanding and logical reasoning. This situation highlights the need for educational innovations that actively engage pupils and provide more relevant, contextual learning opportunities. The Problem-Based Learning (PBL) model, combined with interactive digital learning resources, is one such strategy. This study aims to examine how implementing the Problem-Based Learning model, supported by a digital snakes-and-ladders game, influences the geometric reasoning skills of Year 3 primary school pupils. The study employed a quasi-experimental, non-equivalent control group design and a quantitative methodology. A total of 54 pupils formed the sample, divided into experimental and control groups. The geometric reasoning ability test and student response questionnaire served as the research instruments. Prerequisite tests (homogeneity and normality), an independent-samples t-test for hypothesis testing, and N-Gain for assessing effectiveness were conducted in SPSS version 27. The geometric reasoning abilities of students in the experimental and control groups differed significantly, according to the research findings, with a significance value of 0.045 ($p < 0.05$). An effect size analysis using Cohen's d revealed a moderate effect ($d = 0.55$), indicating that the intervention had a significant practical impact on pupils' geometric reasoning skills. The average post-test score of the experimental class was higher than that of the control group, indicating that the use of digital media in PBL had a more beneficial effect on geometric reasoning skills. According to the N-Gain test results, the experimental class showed a high improvement in geometric reasoning ability (0.72), while the control group showed a moderate improvement (0.43). In addition, the pupils demonstrated very positive responses regarding interest in learning, engagement, collaboration, ease of use of the media, conceptual understanding, and geometric reasoning, with an overall average response rate of 97.44%. These results indicate that integrating digital game media with the Problem-Based Learning (PBL) model not only improves learning outcomes quantitatively but also fosters more interactive, contextual, and student-centered learning. Therefore, the use of the PBL model alongside digital snakes and ladders game media can serve relevant alternative learning strategy to help primary school pupils improve their geometric reasoning skills.

Keywords: problem-based learning, digital snakes and ladders, geometric reasoning, primary school, mathematics learning.

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INTRODUCTION

Education is a consciously and systematically designed process that creates learning experiences enabling students to develop their potential to the fullest, including knowledge, skills, and attitudes. Mathematics education in the 21st century emphasizes the development of higher-order thinking skills, including reasoning, problem-solving, and critical thinking. Geometric reasoning is a key component of mathematical thinking, as it enables students to analyze spatial relationships, interpret geometric concepts, and solve contextual mathematical problems. However, many primary school pupils still struggle to understand abstract geometric concepts, particularly angles, due to teacher-centered instruction and limited use of interactive learning materials. In practice, learning focuses not only on the content delivered but also on the comprehensive development of students' thinking skills. Therefore, the learning process must be designed to be active, interactive, and meaningful so students can construct their own understanding through contextual learning experiences. In primary school mathematics education, the teacher's role is crucial in creating a learning environment that encourages students' active engagement. Mathematics learning requires not only mastery of concepts but also higher-order thinking, including analysis, reasoning, and problem-solving. Effective mathematics learning should provide pupils with opportunities to explore concepts, formulate questions, and construct solutions through systematic reasoning activities that support mathematical understanding and cognitive development (Mukuka et al., 2023). This is particularly important because learning experiences in primary school provide an initial foundation for developing students' thinking skills at subsequent levels.

In line with demands of 21st-century education, students are expected to possess the 4C skills: critical thinking, creativity, collaboration, and communication (Jelodari et al., 2025). One skill that plays a vital role in supporting these is mathematical reasoning. This ability enables students to analyze information, connect concepts, and draw logical and systematic conclusions when solving mathematical problems. Consequently, the development of mathematical reasoning skills is a key focus in modern mathematics education. However, students' mathematical reasoning abilities remain a serious issue both globally and nationally. Findings from the PISA (Program for International Student Assessment), conducted by the OECD (Organization for Economic Co-operation and Development) (OECD, 2021), indicate that Indonesian students' mathematical literacy remains low, particularly in reasoning and problem-solving skills. These findings indicate that the majority of students still struggle to understand mathematical concepts and apply them in real-world contexts. This situation highlights a gap between the demands for higher-order thinking skills and ongoing learning practices in the field. Data on Indonesian students' mathematics proficiency scores are presented in the following figure:

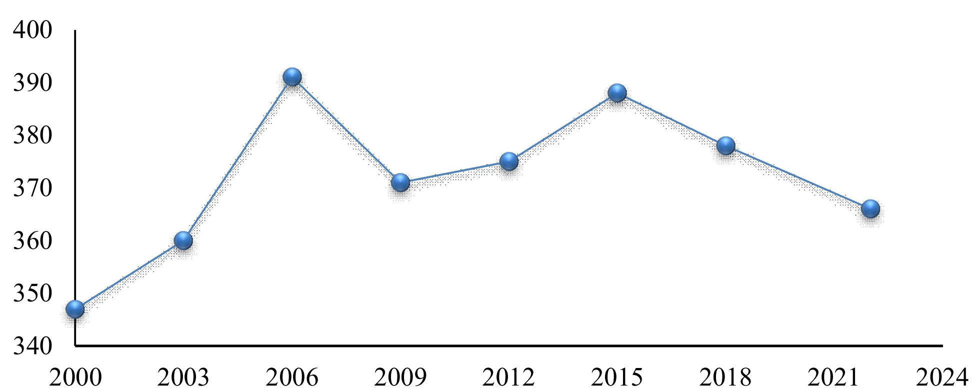

Figure 1. Trends in PISA mathematics scores in indonesia 2000–2022 (OECD, 2023)

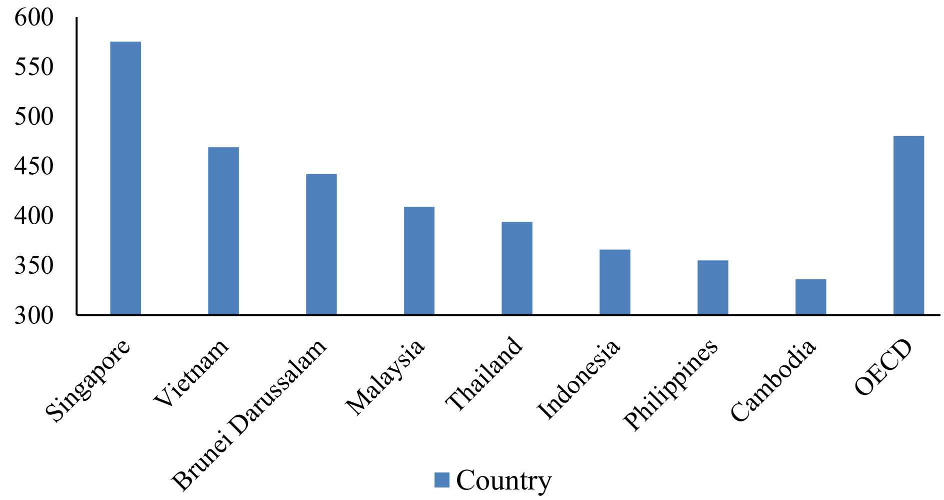

Figure 2. Comparison of average PISA mathematics scores between OECD and ASEAN countries (OECD, 2023)

The results of the Program for International Student Assessment (PISA) show that Indonesia's mathematics performance remains relatively low compared to the OECD average and several ASEAN countries. As shown in Figures 1 and 2, Indonesian students' mathematics scores from 2000 to 2022 have consistently fallen below the OECD average, particularly in reasoning-based problem-solving tasks. This situation reflects the ongoing challenges in developing students' higher-order mathematical thinking skills, including geometric reasoning, which is essential for understanding spatial relationships, analyzing geometric concepts, and solving contextual mathematical problems. One area of mathematics that requires strong reasoning skills is geometry, particularly the concept of angles, which is often considered abstract by primary school pupils. These skills require students not only to understand concepts procedurally but also to analyze relationships between concepts, construct logical arguments, and draw systematic conclusions (Clements & Sarama, 2022; Tarng et al., 2024). However, empirical findings in the field indicate that primary school pupils' geometric reasoning skills remain relatively low. Observations in primary schools in the Kemuning Cluster, Semarang City, indicate that pupils struggle to understand abstract geometric concepts, such as angles, angle types, and angle relationships. Furthermore, pupils are unable to provide logical reasoning for their answers, meaning that the learning process tends to be limited to rote mastery of concepts (Andrijati et al., 2020). This situation indicates that pupils' mathematical reasoning skills have not developed to their full potential. Mathematical reasoning is a crucial competence for supporting higher-order thinking skills. This low level of ability not only impacts mathematical learning outcomes but also pupils' ability to solve contextual problems. Therefore, efforts are needed to improve the learning process, which should not only focus on content delivery but also on encouraging pupils' active engagement in building understanding and developing their reasoning skills.

Students' low geometric reasoning skills are influenced by various factors, including the use of teacher-centered learning models, which provide little scope for students to actively engage in the thinking process. Furthermore, a lack of variety in learning models and the minimal use of interactive learning media exacerbate the situation. Conventional teacher-centered instruction often limits pupils' opportunities to actively participate in mathematical exploration and reasoning processes, whereas interactive digital learning environments can foster more meaningful engagement and independent thinking (Wang et al., 2022). Moreover, the limited availability of learning media that can visualize abstract concepts, particularly in geometry, impedes learning. This makes it difficult for students to understand concepts in depth, resulting in low motivation and interest in learning. Students' active engagement in learning is crucial for developing logical and systematic thinking skills. Therefore, a learning model is needed that encourages active student participation whilst facilitating meaningful thinking.

One alternative learning model is Problem-Based Learning (PBL). This model emphasizes using contextual problems as a starting point for learning, thereby encouraging students to think critically, analyze information, and find solutions independently and collaboratively (Van Hooijdonk et al., 2024). Through this approach, students not only acquire knowledge but also develop deeper mathematical reasoning skills (Stylianides, 2021). Various studies have shown that PBL is an effective approach for mathematics learning, particularly in enhancing reasoning and problem-solving skills. A systematic review found that PBL encourages students to actively construct knowledge by solving contextual problems, thereby enhancing higher-order thinking skills (Ayari et al., 2025). Furthermore, PBL also plays a role in developing mathematical connection skills, namely the ability to meaningfully link various concepts as part of higher-order thinking skills (Anugraheni et al., 2025). At the primary school level, PBL has been shown to increase student participation and deepen conceptual understanding through contextual learning experiences (Noviyana et al., 2025). Furthermore, the problem-solving skills developed through PBL are closely linked to mathematical reasoning abilities, as they involve logical analysis and decision-making.

To achieve optimal learning effectiveness, implementation of the Problem-Based Learning (PBL) model needs to be supported by learning media that align with the cognitive developmental characteristics of primary school pupils and the demands of the digital age. Digital learning media, particularly those packaged as educational games, have been shown to enhance student motivation and engagement in the learning process (Baya'a & Daher, 2023). Furthermore, the use of digital media can also create a more interactive, engaging, and adaptive learning environment tailored to students' learning needs (Giannakoulas & Xinogalos, 2024). Interactive and technology-supported learning environments may enhance pupils' engagement and participation by creating more meaningful, student-centered mathematics learning experiences (Zhang et al., 2022). Recent developments in primary mathematics education have highlighted the growing importance of game-based learning environments in supporting pupils' engagement and participation during classroom instruction. Debrenti (2024) explained that game-based learning experiences can foster more meaningful and interactive mathematics learning by encouraging pupils to actively explore mathematical concepts through enjoyable activities. In geometry learning, interactive game-based activities may also help pupils understand abstract concepts more concretely through visual and participatory experiences.

One medium with the potential to support mathematics learning is the digital snakes and ladders game. This medium is a web-based educational game that systematically integrates game elements with mathematical content. Through interactive, game-based learning activities, pupils are encouraged to actively participate in mathematics instruction, enabling them to understand abstract geometric concepts more concretely through visual and experiential learning (Ramli et al., 2022). In addition to increasing engagement, this medium also encourages pupils to participate more enthusiastically in the learning process, thereby enhancing understanding and learning outcomes. From a constructivist perspective, learning occurs when pupils actively construct knowledge through interaction with their environment and social experiences. Piaget's theory explains that primary school pupils at the concrete operational stage learn more effectively through concrete and visual experiences. Meanwhile, Vygotsky emphasizes the importance of social interaction and collaborative learning in supporting cognitive development. Previous research has shown that the application of the PBL model effectively enhances students' higher-order thinking, including mathematical reasoning (Firdausy et al., 2021; McCashin et al., 2022). Furthermore, the use of digital games has also been shown to increase student interest and learning outcomes (Debrenti, 2024). Furthermore, integrating the Problem-Based Learning model with digital media has yielded better results than conventional learning, increasing student engagement whilst strengthening mathematical reasoning skills (Yanuarto et al., 2025). Thus, the combination of the PBL model and digital games holds great potential for creating more effective and meaningful learning.

In theory, PBL emphasizes learning centered on contextual problem-solving, thereby encouraging pupils to develop critical thinking and reasoning in solving mathematical problems. Previous research has shown that Problem-Based Learning (PBL) can enhance students' mathematical reasoning and problem-solving skills by encouraging active investigation, collaborative discussion, and contextual thinking (Fitriyah et al., 2022). Through authentic problem-solving situations, students are encouraged to construct their own understanding and develop logical reasoning processes. However, most existing research examines learning models and media separately. Limited research exists that integrates the Problem-Based Learning (PBL) model with a digital snakes and ladders game to enhance primary school pupils' geometric reasoning skills, particularly regarding angles. This situation highlights a research gap: the limited number of studies that simultaneously combine the Problem-Based Learning (PBL) model with digital game media within the context of geometry learning in primary schools. In light of this gap, this study offers a new approach by integrating the Problem-Based Learning (PBL) model with digital snakes-and-ladders media to improve students' geometric reasoning skills through interactive, contextual, and enjoyable learning. Therefore, this study aimed to: 1) examine the effect of implementing the Problem-Based Learning model supported by digital snakes and ladders media on the geometric reasoning abilities of Year 3 primary school pupils; and 2) analyze the extent to which the implementation of the Problem-Based Learning model supported by digital snakes and ladders media contributes to improving pupils' geometric reasoning skills. Based on these objectives, the research questions were formulated as follows: 1) What is the effect of implementing a Problem-Based Learning model supported by a digital snakes and ladders game on the geometric reasoning abilities of Year 3 primary school pupils at the Kemuning Cluster, Semarang City? 2) To what extent does the implementation of the Problem-Based Learning model supported by a digital snakes and ladders game contribute to improving pupils' geometric reasoning skills?.

■ METHOD

Prior to conducting the research, preliminary classroom observations were conducted to identify pupils' difficulties in understanding the concept of angles and geometric reasoning. The observations revealed that pupils struggled to interpret angular relationships and solve contextual geometry problems, particularly during teacher-centered lessons.

Sample

The population of this study comprised all Year 3 classes from primary schools within the Kemuning Cluster, Semarang City. In this research, each class was treated as a cluster because the study involved naturally occurring classroom groups that had been formally organized by the schools prior to the research. A cluster random sampling technique was employed to determine the research sample. Initially, all Year 3 classes within the Kemuning Cluster were identified as the population clusters. Subsequently, two classes were randomly selected through a simple lottery procedure. Following the random selection process, one class from SDN Wonosari 03 was assigned as the experimental group, whilst one class from SDN Wonosari 01 served as the control group. The final sample consisted of 54 pupils, including 26 pupils in the experimental class and 28 pupils in the control class. Prior to the implementation of the intervention, preliminary analyses were conducted to assess the normality and homogeneity of the data, ensuring that both groups had relatively comparable initial characteristics. Before assigning classes to the experimental or control groups, normality and homogeneity tests were conducted on the students' initial scores to ensure the data were suitable for experimental analysis. The results showed a significance level greater than 0.05, confirming that the data were normally distributed and the variances were homogeneous, thus fulfilling the necessary assumptions for experimental research.

Research Design and Procedure

This study employed a quantitative approach using a quasi-experimental design, specifically a nonequivalent control group design. This design was chosen because the researcher did not conduct full individual randomization and could not control all external variables; instead, they utilized pre-existing classes (Usmani et al., 2025). The research design can be illustrated as follows:

Table 1. Nonequivalent control group design

Group	Pre-test	Treatment	Post-test
Experimental Class	O_1	X_1	O_2
Control Class	O_3	X_2	O_4

This study employed a two-group design comprising an experimental class and a control class. The experimental class received instruction using the PBL model, supported by a digital snakes-and-ladders game (X1), whilst the control class followed conventional teaching methods without this medium (X_2). Both groups were given a pre-test (O_1 for the experimental class and O_3 for the control class) prior to the intervention to assess their initial geometric reasoning abilities. Following the intervention, a post-test (O, for the experimental class and O_4 for the control class) was administered to measure changes in geometric reasoning ability. The teaching period spanned three sessions, each lasting 2 × 35 minutes. In the experimental class, learning took place through the PBL stages: problem orientation, student organization, independent and group investigations, development and presentation of results, and analysis and evaluation. The digital snakes and ladders game served as an interactive tool to facilitate students' concrete understanding of angles. Conversely, the control class used conventional teaching methods, including lectures, question-and-answer sessions, and problem-solving exercises. This study was conducted at two selected primary schools in the Kemuning Cluster, Semarang City, during the second semester of the 2025/2026 academic year.

To provide a clearer visual representation of students' scores and learning progress, scatter plots were used to illustrate the relationship between pre-test and post-test scores in both the experimental and control groups.

Figure 3 presents the distribution of pupils' pre-test and post-test scores in both the experimental and control groups. The diagonal reference line represents equal pretest and posttest scores. Data points positioned above the diagonal line indicate improvements in pupils' scores after the learning intervention. The scatter plot shows that most pupils in the experimental group experienced greater score improvements than those in the control group. In addition, the experimental group scores tended to cluster at higher posttest values, indicating that the implementation of the Problem-Based Learning model, supported by digital snakes-and-ladders media, contributed positively to improving pupils' geometric reasoning abilities.

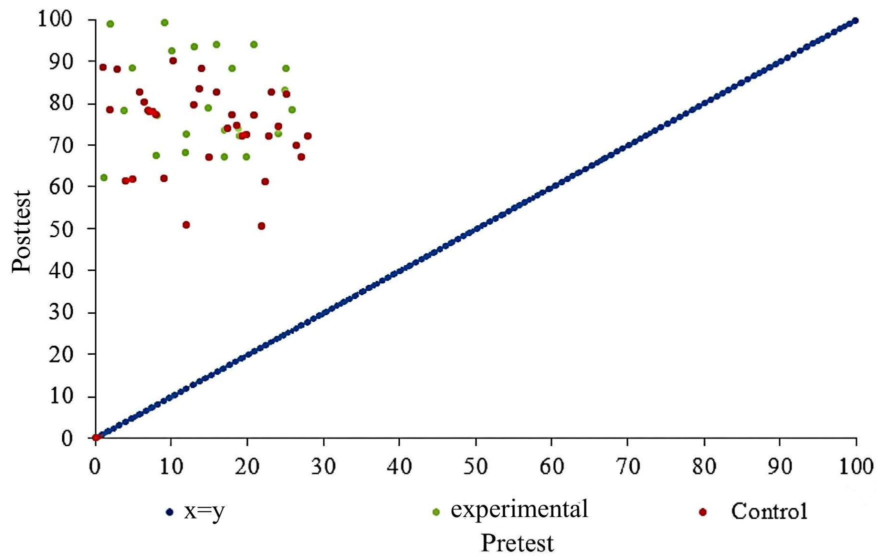

Figure 3. Scatter plot of pre-test and post-test scores for the experimental and control groups

Instruments

Data in this study were collected through a geometric reasoning ability test and supplemented by a student response questionnaire. The ability test measured students' geometric reasoning skills, whilst the questionnaire provided supporting data on students' responses to the implementation of the PBL model, aided by the digital Snakes and Ladders game, in the experimental class. The student response questionnaire was developed based on indicators relating to interest in learning, motivation, engagement, collaboration, conceptual understanding, geometric reasoning, and the stages of Problem-Based Learning (PBL). The questionnaire consists of 15 statements using a four-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. Prior to use, all instruments underwent content validity assessment by three mathematics experts using Aiken's V analysis. The main instrument was the geometric reasoning ability test, administered as a pretest and a posttest. Test items were developed based on mathematical reasoning indicators, including non-routine problem-solving, analysis, synthesis, generalization, and justification. The test consists of six descriptive questions with a maximum raw score of 18, which is then converted to a scale of 0–100. The validity of the test items was evaluated using the product-moment correlation method, with items considered valid if the calculated r value exceeded the critical r table value. The internal consistency of the questionnaire was analyzed using Cronbach's Alpha to assess the reliability of the items. A coefficient value above 0.70 indicates acceptable consistency (Mukuka et al., 2023). The results demonstrated that all instrument items were valid and possessed satisfactory reliability, indicating that the instruments were appropriate for use in this study. In addition, item validity was analyzed using Pearson's product-moment correlation to ensure that each item appropriately measured the intended construct. The questionnaire instrument, used to obtain supporting data on pupils' responses to the learning intervention, also showed satisfactory internal consistency, indicating that it was sufficiently reliable for data collection. Nevertheless, future studies are encouraged to employ more advanced validation techniques, such as Confirmatory Factor Analysis (CFA), to provide stronger evidence of construct validity and improve the robustness of the instrument evaluation.

Data Analysis

Data analysis in this study was conducted in two main phases: preliminary analysis and hypothesis testing. All analyses were performed using SPSS version 27, with the significance level set at 0.05. Preliminary analysis included tests for normality and homogeneity. The normality test assessed whether the data followed a normal distribution, whilst the homogeneity test evaluated whether the variances between the experimental and control groups were equal. Data were considered normal and homogeneous if the significance value was greater than 0.05. Once these assumptions were confirmed, hypothesis testing was conducted using an independent-samples t-test to compare geometric reasoning ability between the two groups. A two-tailed significance level was used as the decision criterion, where $p < 0.05$ indicates a statistically significant difference. To measure the extent of student improvement, the N-Gain test was used, with effectiveness categorized as low ($g<0.3$), moderate ($0.3 < g < 0.7$), or high (ge"0.7) according to Sukarelawan et al. (2024). The supporting data from the questionnaire were analyzed descriptively using percentages. The percentage of student responses was calculated by dividing the total score obtained by the maximum possible score, then multiplying the result by 100. The questionnaire consisted of 15 items measured using a four-point Likert scale ranging from strongly disagree (1) to strongly agree (4). The overall percentage score was used to interpret student responses to implementation of the Problem-Based Learning model supported by digital snakes-and-ladders media.

RESULT AND DISCUSSION

This study aims to analyze the effect of implementing a Problem-Based Learning model, supported by a digital snakes-and-ladders game, on the geometric reasoning of Year 3 primary school pupils. The presentation of the research results includes descriptive analysis, prerequisite tests, hypothesis testing, and effectiveness testing (N-Gain), supported by a description of the learning process and pupils' responses to learning activities.

Geometric Reasoning Ability

The results of the descriptive analysis indicate an improvement in students' geometric reasoning skills in both groups, both the experimental and control classes; however, improvement in the experimental class appears to be more optimal.

Table 2. Results of the descriptive analysis of students' geometric reasoning skills

Class	Test	Min	Maks	Mean	Std. Deviation
Experimental	Pre-test	22.22	83.33	56.19	18.34
Experimental	Post-test	61.11	100	80.76	12.39
Control	Pre-test	33.33	88.89	53.17	15.22
Control	Post-test	50	94.44	74.20	11.13

Based on Table 2, the average pre-test score in the experimental class was 56.19, whilst in the control class it was 53.17. The difference in scores is relatively small, indicating that students in both groups had equivalent initial geometric reasoning abilities. This equivalence in initial ability is important as it suggests that differences in outcomes at the final stage of the study were influenced more by treatment administered than by differences in students' initial abilities. Following the instructional intervention, both groups showed significant improvement. The average post-test score in the experimental class increased to 80.76, whilst in the control class it increased to 74.20. This improvement indicates that the learning process implemented in both classes positively impacted students' geometric reasoning abilities. However, upon further comparison, the improvement in the experimental class was greater than in the control class, indicating that application the PBL model, supported by the digital snakes and ladders game, contributed more effectively to enhancing geometric reasoning skills. In addition to the mean scores, changes were also observed in the standard deviation. In the experimental class, the standard deviation decreased from 18.34 to 12.39, whilst in the control class, it decreased from 15.22 to 11.13. This reduction in standard deviation indicates that the variation in students' abilities decreased following the learning process, suggesting an improvement in the equality of students' abilities. In other words, the learning approach implemented not only improved students' average ability but also reduced the gap between students within the class.

Pedagogically, these findings suggest that the learning approach used in the experimental class accommodates differences in student ability more effectively. The PBL model provides opportunities for students to actively engage in the learning process through exploration, discussion, and problem-solving, enabling each student to develop their understanding in line with their individual abilities. Meanwhile, using a digital snakes-and-ladders game helps students visualize abstract geometric concepts more concretely, making the material easier to understand. These results also indicate that improvements in geometric reasoning ability are influenced not only by cognitive activities but also by students' engagement in an interactive and meaningful learning process. Learning that actively involves students enables them to construct knowledge independently, resulting in deeper and more enduring understanding. These findings are consistent with those of Andrijati et al. (2020), who state that primary school pupils' mathematical reasoning skills develop optimally when learning is designed to actively involve pupils in the thinking process. Thus, the results of this descriptive analysis provide an initial indication that implementing an appropriate learning model, particularly one oriented towards student activities and supported by interactive media, has great potential to improve students' geometric reasoning skills in a more equitable and sustainable manner. The difference in the improvement of geometric reasoning skills between the experimental and control classes was influenced not only by the learning model but also by the use of media that supported the visualization of concepts. In the experimental class, learning was supported by a digital snakes-and-ladders game that integrated game elements with geometric content, thereby facilitating students' meaningful understanding of angle concepts. An illustration of the media used in the study is shown in Figure 4.

Prerequisite Analysis Test

Prior to hypothesis testing, prerequisite analyses were conducted, including normality and homogeneity tests. These tests aim to verify that the data meet the necessary statistical assumptions and are suitable for analysis using parametric methods. The results of the normality and homogeneity shown in Table 3.

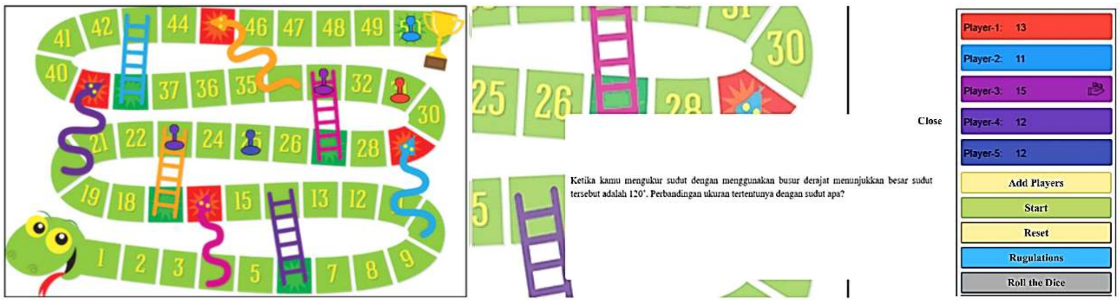

Figure 4. Digital snakes-and-ladders media

Table 3. Results of the normality test

Data	Class	Sig.	Information
Pre-test	Experimental	0.109	Normal
Pre-test	Control	0.109	Normal
Post-test	Experimental	0.051	Normal
Post-test	Control	0.308	Normal

Normality testing was conducted using the Shapiro-Wilk test to assess whether the data were normally distributed. According to Table 3, all significance values for the pre-test and post-test data in the experimental and control groups were greater than 0.05 (Sig. > 0.05). Specifically, the pre-test data for both classes had a significance value of 0.109, whilst the post-test data had a significance value of 0.051 for the experimental class, and 0.308 for the control class. These results indicate that the data are normally distributed. As the assumption of normality is met, parametric statistical tests are considered appropriate for further analysis. In practical terms, a normal distribution indicates that students' scores are evenly distributed, meaning analysis results can more accurately reflect the population. Therefore, all datasets are deemed to meet the criteria for normality.

Next, a homogeneity test was conducted to check whether variances between the experimental and control classes were similar. Results the homogeneity test are shown in Table.

Table 4. Results of the homogeneity test

Data	Sig.	Description
Pre-test	0.129	Homogeneous
Post-test	0.197	Homogeneous

According to Table 4, the significance values for the pre-test and post-test data were 0.129 and 0.197, respectively, both exceeding the 0.05 threshold (Sig. > 0.05). This indicates that the variance between the two groups is homogeneous. This homogeneity indicates that variability between the experimental and control classes is comparable, allowing a fair and unbiased comparison of learning outcomes in geometric reasoning between groups. Based on the results of the normality and homogeneity tests, the research data meet the basic assumptions for parametric analysis, namely normality and homogeneity of variances. Consequently, the data are suitable for hypothesis testing with the independent-samples t-test.

Hypothesis Testing

Hypothesis testing was conducted using an independent-samples t-test to determine whether students' geometric reasoning abilities differed between the two classes.Results from the independent-samples t-test show a significance value of 0.045 (Sig. < 0.05), indicating that the null hypothesis (H_0) is rejected whilst the alternative hypothesis (H_a) is not rejected. Demonstrates a significant impact of implementing the PBL model and supported digital snakes-and-ladders media on students' geometric reasoning skills. Analytically, this indicates that the observed improvement in geometric reasoning is attributable to the implemented learning model and is not merely coincidental. Problem-Based Learning emphasizes contextual problem-solving activities that encourage pupils to actively construct knowledge through investigation, collaboration, and reflective thinking processes (Jelodari et al., 2025). Previous studies have demonstrated that integrating Problem-Based Learning with digital game-based activities can significantly enhance pupils' higher-order thinking skills and mathematical reasoning in primary education settings (Tong et al., 2022). To reinforce the interpretation of the t-test results, an effect size analysis was conducted using Cohen's d. This analysis yielded a Cohen's d value of 0.55, which falls within the category of a moderate effect. These results indicate that implementing the Problem-Based Learning (PBL) model, supported by a digital snakes-and-ladders game, has a significant practical impact on students' geometric reasoning skills.

Effectiveness Test (N-Gain)

To determine the extent of improvement in students' abilities, an N-Gain test was conducted.

Table 5. N-Gain test results

Class	N-Gain	Category
Experimental	0.72	High
Control	0.43	Moderate

N-Gain test results indicate that the experimental class achieved a score of 0.72, categorized as high, whilst the control class scored 0.43, categorized as moderate. These findings suggest that the improvement in students' geometric reasoning skills was more effective in the experimental class than in the control class. Theoretically, this supports the view that mathematical reasoning skills develop optimally through a learning approach that engages students in higher-order thinking and active problem-solving activities (Haider & Yahya, 2025).

Description of the Learning Process

Learning in the experimental class showed higher student engagement than in the control class. The implementation of the PBL model encouraged students to actively identify problems, engage in discussions, and express their ideas. The digital snakes and ladders game served as an effective supporting tool, making the learning process more interactive and stimulating. Conversely, learning in the control class was largely teacher-centered, which limited students' active engagement in the thinking process. Consequently, development of students' reasoning skills in the control class was less optimal than in the experimental class. These findings are consistent with Cevikbas & Kaiser (2022), who reported that student-centered and interactive mathematics learning environments offer greater opportunities for pupils to actively engage in mathematical thinking than conventional instructional approaches.

Student Response to Learning

To provide a more comprehensive interpretation of the students' responses, the questionnaire results were grouped into several categories, including interest and motivation to learn, ease of use of the media, engagement and collaboration, conceptual understanding and geometric reasoning, and the PBL learning process and reflection.

Table 6. Results of the students' responses to the questionnaire

Response Category	Frequency	Percentage
Strongly Agree	349	89.49%
Agree	35	8.97%
Disagree	5	1.28%
Strongly Disagree	1	0.26%
Total	390	100%

The questionnaire results showed that pupils generally responded positively to the implementation of the Problem-Based Learning model supported by digital snakes-and-ladders media. Most responses were categorized as "Strongly Agree" (89.49%), followed by "Agree" (8.97%). Only a small proportion of responses fell into the "Disagree" (1.28%) and "Strongly Disagree" (0.26%) categories. These findings indicate that the learning model and media were positively received by the pupils and contributed to greater engagement and participation during mathematics learning activities.

The percentage of pupils' responses was calculated by dividing the frequency of responses in each category by the total number of responses to the questionnaire, then multiplying by 100%. The results of the questionnaire showed that students in the experimental class gave a very positive response to the learning process, with an average response rate of 97.44% (very good category). The questionnaire results indicated highly positive pupil responses to the implementation of the Problem-Based Learning model supported by digital snakes-and-ladders media, with an average percentage score of 97.44%. Nevertheless, the predominance of highly positive responses may indicate response bias, particularly because most pupils selected favorable response categories for nearly all questionnaire items. This condition may have been influenced by pupils' enthusiasm for using interactive digital learning media during the intervention. Therefore, the questionnaire findings should be interpreted with caution as supporting evidence rather than as the sole indicator of the intervention's effectiveness. These results align with the findings of Serrano-Baena et al. (2025), who noted that digital game media can increase student motivation and foster deeper conceptual understanding. Furthermore, Kriswandani & Kusuma (2025) reported that combining the problem-based learning model with game media resulted in significant improvements in reasoning skills.

Description of Students' Geometric Reasoning and Effect of Media-Assisted Models

The analysis results indicate that students' geometric reasoning skills improved in both groups, but improvement was greater in the experimental class. The average pre-test score in the experimental class was 56.19 and in the control class was 53.17, indicating that the initial abilities of both groups were relatively similar. Following intervention, the average post-test score rose to 80.76 in the experimental class and 74.20 in the control class. The larger increase in the experimental class indicates that applied learning has a greater impact on students' development of geometric reasoning. Furthermore, the reduction in standard deviation in both classes suggests that students' abilities became more evenly distributed, particularly in the experimental class. This indicates that the intervention not only improved average learning outcomes but reduced variation in students' abilities. Conceptually, these findings suggest that mathematical reasoning skills develop more optimally through learning that actively engages students in the thinking process. The Problem-Based Learning (PBL) model enables students to engage in problem-solving, discussion, and concept exploration, thereby fostering the development of logical and systematic thinking skills. Furthermore, the use of a digital snakes and ladders game helps to visualize abstract geometric concepts in a more concrete form, in line with the cognitive development of primary school pupils.

The results of the hypothesis test showed a significance level of 0.045 (Sig. < 0.05), indicating a significant difference between the experimental and control classes. Thus, the implementation of the PBL model, supported by the digital snakes-and-ladders game, has been shown to affect students' geometric reasoning skills. A moderate effect size (Cohen's d = 0.55) indicates that the integration of digital game-based media into the PBL model not only produced statistically significant differences but also contributed to a practically meaningful improvement in students' geometric reasoning skills. Analytically, these results suggest that the improvement in students' abilities in the experimental class did not occur by chance, but was the result of the instructional treatment provided. The PBL model encourages students to think critically by identifying problems, discussing them, and developing solutions, thereby making the learning process more meaningful. The use of digital snakes and ladders also enhances learning effectiveness by creating a more interactive and enjoyable atmosphere. This medium helps students understand angles through visualization and hands-on learning, thereby increasing engagement and motivation. These findings suggest that the intervention is quite effective in supporting pupils' understanding of geometric concepts and reasoning processes in mathematics learning at the primary school level. Conversely, in the control class, the teacher-centered learning model limited student engagement, resulting in suboptimal development of reasoning skills.

Contribution to Learning Effectiveness

The N-Gain test results show that the experimental group achieved a score of 0.72, categorized as high, whilst the control group scored 0.43, categorized as moderate. This indicates that the experimental group experienced a greater improvement in geometric reasoning skills than the control group. The high N-Gain score in the experimental group indicates that problem-based learning, when supplemented with digital media, effectively fosters higher-order thinking skills. Students are not only able to understand concepts but also to analyze information, draw conclusions, and logically justify their solutions. Furthermore, the questionnaire revealed a student response rate of 97.44%, which is considered highly positive, reflecting an engaging and easily understandable learning experience. The interactive and contextual presentation of the material helped students remain engaged and facilitated better understanding. The students' highly positive responses across various aspects indicate that using a digital snakes-and-ladders game within the PBL model not only enhances cognitive achievement but also fosters motivation, engagement, collaboration, and active participation throughout the learning process.

In summary, the research findings indicate that combining the PBL model with a digital snakes-and-ladders game has a significant, beneficial effect on students' geometric reasoning. These results support the notion that a student-centered learning approach, which is interactive and contextually relevant, fosters a deeper, more meaningful learning experience. This finding is consistent with constructivist learning theory, which emphasizes that meaningful learning occurs when students actively engage with learning materials, their peers, and contextual problems. Therefore, integrating the PBL model with digital snakes-and-ladders media not only improves learning outcomes but also enhances the quality of pupils' thinking, particularly in geometric reasoning.

This study used an independent-samples t-test to analyze differences between groups.

However, future research is advised to employ more advanced statistical techniques, such as Analysis of Covariance (ANCOVA), using pre-test scores as covariates to more accurately account for initial differences between groups.

CONCLUSION

The application of the PBL model with digital snakes-and-ladders media significantly enhances primary school pupils' geometric reasoning skills, aligning with the research objectives. The more contextual learning experience provided by problem-based learning, reinforced by interactive media, enables pupils to construct knowledge through logical, analytical, and systematic thinking processes alongside procedural conceptual understanding. A pedagogical innovation that successfully links pupils' concrete thinking with the requirements of higher-order thinking skills in mathematics learning integration learning model with digital media. Findings from this study also emphasise importance student-centred learning improving the quality of learning procedures and outcomes. In addition to enhancing pupils' motivation and engagement, the use of digital game-based media encourages teamwork and social interaction, both of which are crucial for the development of reasoning skills. Consequently, the *PBL* model combined with digital game-based media, specifically the snakes and ladders game, offers a relevant and promising alternative learning approach that meets the requirements of 21st-century education. In practical terms, it is recommended that educators create a variety of digital learning resources tailored to students' needs and characteristics of the subject matter. To enhance the generalisability of these findings, further research is also encouraged to investigate the application of this model across various mathematical topics and different levels of education.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of this manuscript, the authors employed DeepL to assist with language refinement, grammar checking, and enhancing the clarity of the academic writing. All ideas, data analyses, interpretations, and conclusions presented in this article were developed and reviewed by the authors. The authors take full responsibility for the content of this publication.

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