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Application of Game-Based Outdoor Learning to Mathematical Spatial Ability

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ABSTRACT

The majority of students have very low levels of spatial thinking ability. Spatial ability is essential for students to better understand geometry topics, particularly polyhedra (solid figures with flat faces). This condition is further exacerbated by the use of conventional mathematics teaching methods, which primarily focus on lectures, textbooks, and drill exercises. As a result, classroom learning often leads students to feel bored and less enthusiastic. To address this issue, the researcher implemented a game-based outdoor learning approach. Therefore, this study aims to examine the improvement in the mathematical spatial ability of ninth-grade students after the implementation of game-based outdoor learning. The research subjects were students of class IX B at one junior high school in Jambi City. This study employed a quantitative descriptive pre-experimental method, using a One-Group Pretest–Posttest Design, in which only one experimental class was given the treatment. To determine the level of improvement in students' mathematical spatial ability, N-gain analysis was used. The N-gain value was calculated by comparing the difference between pretest and posttest scores, and the results were interpreted into high, moderate, or low improvement categories. Based on descriptive statistical analysis, the research data showed that the minimum student score was 20, the maximum score was 86.6, and the mean score of students' mathematical spatial ability was 56.6357, with a standard deviation of 17.44458. Out of 28 students, 3 students showed a high improvement in spatial ability, 20 students showed moderate improvement, and 5 students showed low improvement. The implementation of game-based outdoor learning was found to enhance students' spatial ability, particularly in the geometry of polyhedra, by integrating physical and collaborative activities to achieve enjoyable learning objectives.

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Introduction

Geometry is a topic in mathematics learning that requires a sufficient level of mathematical understanding of the concepts involved (Silalahi et al., 2020). According to Hibatullah et al. (2020), geometry represents an abstract presentation of visual and spatial experiences related to shapes, patterns, measurement, and mapping. At the junior high school level, particularly in Grade IX, one of the geometry topics taught is polyhedra (solid figures with flat faces). In learning polyhedra, students are required to achieve specific competency standards, namely understanding the properties of cubes, rectangular prisms, prisms, and pyramids along with their components, as well as being able to determine their measurements (Ningsih & Haerudin, 2019). To achieve these competency standards, students' mathematical spatial ability is essential, as each indicator of spatial ability is closely related to the existing competency standards.

According to Silalahi et al. (2020), spatial ability refers to an individual's capacity to imagine objects in three-dimensional space. The spatial abilities proposed by Maier (1998) include spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation. Spatial perception is the ability to identify the position of an object being observed in either a horizontal or vertical orientation. Spatial visualization refers to the ability to represent and understand rules of transformation or the rearrangement of components of a figure, whether from three-dimensional to two-dimensional forms or vice versa. Mental rotation is the ability to accurately and precisely rotate two-dimensional and three-dimensional objects. Spatial relations involve the ability to understand the arrangement of an object and its parts, as well as the relationships among them. Spatial orientation is the ability to observe and perceive an object from various viewpoints or perspectives.

Spatial ability is crucial for understanding and acquiring knowledge of geometric forms (Khofifah et al., 2022). Therefore, it is essential for students to possess spatial ability in order to better comprehend geometry topics, particularly polyhedra (solid figures with flat faces). Research by Ningsih & Haerudin (2019) indicates that spatial ability has a significant influence on students' success in solving geometry problems. However, findings by Putri & Yulia (2024) reveal that the majority of students have very low levels of spatial thinking ability. This condition is further exacerbated by the continued use of conventional mathematics teaching methods, which focus primarily on lectures, textbooks, and drill-based exercises (Nurwijaya, 2022). Consequently, this approach negatively affects students' ability to apply abstract concepts to contextual situations as well as their capacity to solve real-world problems (Nurwijaya, 2022).

Based on observations conducted at SMP Negeri 9 Jambi City, it was found that students' mathematical spatial ability remains at a low level. Students were still unable to provide correct responses for each indicator of the given spatial ability tasks. In addition, interviews with one of the students revealed that mathematics learning is always conducted inside the classroom, which often leads to feelings of boredom and a lack of motivation. Therefore, an appropriate instructional approach is required to enhance students' motivation and enthusiasm for learning.

One learning approach that is known to enhance students' motivation and enthusiasm for learning is outdoor learning (Tibe et al., 2023). Outdoor learning is characterized by instructional activities conducted outside the classroom; however, this approach does not disregard the relevance of the learning topics being taught, even though the learning atmosphere is more relaxed compared to conventional classroom instruction (Tibe et al., 2023). During outdoor learning activities, teachers are required to create an enjoyable learning environment and actively engage students in the learning process (Mahendra et al., 2024).

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Enjoyable learning can be created through games (Fadhilah & Sholikin, 2025). Games are defined as enjoyable activities and play an important role in students' acquisition of new skills (Ulhusna et al., 2020). Games can be utilized as learning media, and their use in instructional activities has been shown to be effective in increasing students' learning interest (Wulandari et al., 2020). Some benefits of learning through play include reducing excessive seriousness that may hinder learning, alleviating stress in the learning environment, encouraging full student engagement, enhancing the learning process, fostering creativity, achieving learning objectives subconsciously, gaining meaningful learning experiences, and positioning students as active subjects of learning (Wulandari et al., 2020). Therefore, it is important for teachers to implement game-based learning strategies to facilitate more interactive and less monotonous learning experiences (Mahendra et al., 2024).

Previous research conducted by Puteri & Mariana (2024) demonstrated that the design of spatial outdoor learning activities is effective, as it generates learning activities such as measuring scale by rounding actual object measurements to the nearest tens, estimating measurements of the school field using surrounding intact objects, determining the appropriate scale, drawing a layout of the school field, and drawing conclusions. Similarly, a study by Kurnila et al. (2019) found that the use of game-based media in learning is effective in improving students' spatial ability, as evidenced by students' ability to identify plane figures with equal dimensions, recognize plane figures with the same properties despite differences in size or color, and combine several plane figures into figures of the same or new shapes. However, based on these previous studies, there has been no research that integrates outdoor learning with game-based learning. This gap also presents a challenge for educators to develop innovative learning approaches that are easy for students to understand, meaningful, and enjoyable (Sofnidar et al., 2017). Therefore, this study seeks to integrate outdoor learning with game-based learning to enhance students' mathematical spatial ability in geometry instruction, particularly in the topic of polyhedra (solid figures with flat faces).

The focus of this study is the implementation of game-based outdoor learning. The novelty of this research lies in the specifically designed implementation of game-based outdoor learning to develop students' mathematical spatial ability. Unlike previous studies that primarily emphasized general learning outcomes, this study focuses its analysis on the aspect of mathematical spatial ability through game-based activities that utilize the real environment as learning objects (Sari et al., 2018). The research question of this study is: "How does the mathematical spatial ability of Grade IX B students at SMP Negeri 9 Kota Jambi improve after the implementation of game-based outdoor learning?" The purpose of this study is to examine the improvement in the mathematical spatial ability of Grade IX B students at SMP Negeri 9 Kota Jambi following the implementation of game-based outdoor learning.

Method

Type of Research

This study aims to examine the improvement in students' mathematical spatial ability after participating in game-based outdoor learning. The study employed a quantitative descriptive research design, which allows the researcher to systematically describe the improvement in students' mathematical spatial ability following the implemented learning activities. This Methods section presents a structured explanation of the research design used and the rationale for selecting it, the research subjects, the research instruments along with the reasons for their use, the data collection procedures, and the data analysis techniques applied to obtain the research findings. Through this study, the researcher expects to provide strong empirical contributions to instructional strategies that can be implemented in schools in Indonesia.

The quantitative research design employed in this study is a pre-experimental design. The specific form of the pre-experimental design used is the One-Group Pretest–Posttest Design, in which only one experimental class is involved and receives the treatment. A spatial ability test is administered before the treatment (pretest) and after the treatment (posttest) to the experimental class. The research paradigm is illustrated as follows:

O	X	O

Notes:
X = treatment administered
O = spatial ability test

In this study, the One-Group Pretest–Posttest Design is illustrated as follows:

O The pretest was administered to measure students' initial mathematical ability	X Game-Based Outdoor Learning	O The posttest was administered to measure students' mathematical spatial ability

Figure 1. The One-Group Pretest–Posttest Research Design

Before the learning activities, the researcher administered a pretest to measure students' initial mathematical ability. The researcher then implemented game-based outdoor learning on the topic of polyhedra (solid figures with flat faces) in one experimental class. After the learning activities, a posttest was administered to measure students' mathematical spatial ability.

Population and Sample

Population in this quantitative study consisted of all Grade IX students at SMP Negeri 9 Kota Jambi in the 2025/2026 academic year. This study did not employ a control group and involved only one experimental class. Therefore, the sample comprised all research subjects, namely the 28 students of Grade IX B at SMP Negeri 9 Kota Jambi.

Instruments

Instruments used in this study consisted of a mathematical spatial ability test (pretest and posttest) and observation sheets to assess the implementation of learning activities by both the teacher and the students. The mathematical spatial ability test items were developed based on a test blueprint that had been previously constructed in accordance with the learning objectives. Table 1 presents the blueprint of the mathematical spatial ability test instrument.

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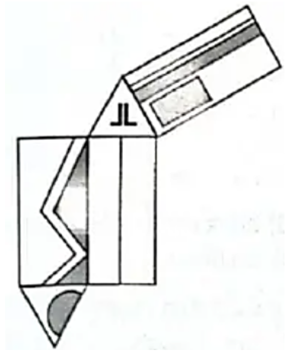
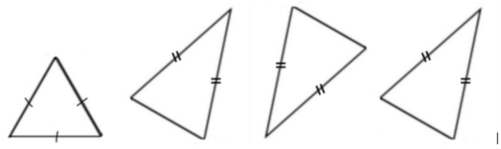
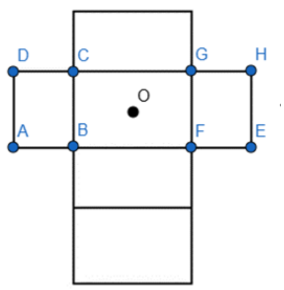
Table 1. Blueprint of the Pretest and Posttest Mathematical Spatial Ability Test Instrument

Indicators of Learning Objective Achievement	Spatial Ability Indicators	Descriptors of Spatial Ability	Question Number	Questions
Students are able to construct the net of a triangular prism.	*Spatial perception*	Identifying spatial figures positioned horizontally or vertically from different perspectives.	1	The figure below shows a triangular prism net with different patterns on each face.  If the triangular prism net is changed to a horizontal position, draw the resulting figure!
Students are able to construct the net of a triangular pyramid.	*Spatial visualization*	Visualizing the actual shape of a three-dimensional figure and determining its position after being manipulated.	2	Observe the object shown in the figure below!  From the objects above, draw the net of the three-dimensional figure that can be formed!
Students are able to construct a quadrilateral prism from its net.	*Mental rotation*	Identifying vertices and the distances between points of a three-dimensional figure after rotation.	3.a	Observe the following figure!  a. The figure above shows the net of a quadrilateral prism. The net will be rotated 90° clockwise around the center point O. Draw the resulting figure along with its vertices!
	Spatial relation	Determining the distance or relationships between points, lines, and planes in space.	3.b	b. From the rotation result, it is known that plane ABCD forms the top (cover) and plane EFGH forms the base of the quadrilateral prism. Draw the quadrilateral prism based on this information!
Students are able to construct a quadrilateral pyramid from its net.	*Spatial orientation*	Visualizing and drawing the three-dimensional figure from a	4	Observe the square-based pyramid net below!

	specific perspective.	 If the net is folded, it will form a square-based pyramid with the face patterned with a circle at the front. Then, the pyramid is rotated 270° counterclockwise. Determine and draw the front face pattern of the square-based pyramid after the rotation!

The mathematical spatial ability test items were validated by an expert in mathematics education. The aspects assessed included the questions, construct, and language. The evaluation used a rating scale ranging from 1 to 4, with the following criteria: 1) Not Relevant, 2) Weakly Relevant, 3) Moderately Relevant, and 4) Highly Relevant. The validation results obtained from the mathematics education expert indicated that, overall, the mathematical spatial ability test items are suitable for use. Table 2 presents the results of the instrument validation for the mathematical spatial ability test.

Table 2. Validation Results of the Students' Mathematical Spatial Ability Test Items

No	Aspect	Assessment Criteria
1	Question	The items are aligned with the previously formulated learning outcome indicators. The items correspond to the learning objectives. The test items are sufficient to assess students' spatial ability on the topic of polyhedra (solid figures with flat faces). The test items fulfill the spatial ability indicators proposed by Maier, which include: a. *Spatial Perception* the ability to identify the position of an object being observed in either horizontal or vertical orientation. b. *Spatial Visualization* the ability to represent and understand transformation rules or rearrangement of components of a figure, whether from three-dimensional to two-dimensional form or vice versa. c. *Mental Rotation* the ability to accurately and precisely rotate two-dimensional and three-dimensional objects. d. *Spatial Relation* the ability to understand the arrangement of an object and its parts, as well as the relationships among them. e. *Spatial Orientation* the ability to observe and perceive an object from various viewpoints.
2	Construct	The main idea of each item is clearly formulated. The wording of each item is stated explicitly. The item does not provide clues to the answer. The items are independent of one another.
3	Language	The item sentences are formulated in a communicative manner. The sentences use proper and correct Indonesian spelling. The item wording does not create ambiguity or misinterpretation. Common language/words are used (not local dialect). The items do not contain words that may offend students. The items do not contain content related to ethnicity, religion, race, or societal groups. Instructions for completing the items are clearly written.
		Category

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Furthermore, the instrument used in this study included observation sheets to assess the implementation of learning activities by the teacher and students. The teacher observation sheet aimed to evaluate the extent to which the learning activities were carried out by the teacher in the experimental class. The observation sheet was completed by checking the statements in the appropriate columns based on a rating scale, with the following scores:

1 : Not implemented
2 : Partially implemented
3 : Moderately implemented
4 : Well implemented

Table 3. Blueprint of the Teacher Observation Sheet for the Implementation of Game-Based Outdoor Learning

Steps	Observed Aspect	Item
	Preliminary Activities	
Orientation	Teacher greets the students	1
	Teacher asks students to pray, led by the class leader	2
	Teacher checks student attendance	3
	Teacher conveys the topic and material to be learned	4
Aperception	Teacher reviews prerequisite material	5
Motivation	Teacher provides motivation	6
Providing Reference	Teacher explains the learning objectives and strategies	7
	Teacher divides groups, explains the game, distributes worksheets (LKPD), and shows images to be answered competitively	8, 9, 10, 11, 12
	Main Activities	
Implementation	Teacher instructs students to go to the location and complete each mission on the worksheet	13, 14, 15
Follow-up	Teacher discusses learning outcomes through presentations, determines game winners, and summarizes the lesson	16, 17, 18, 19, 20, 21
	Closing Activities	
Closure	Teacher gives students the opportunity to ask questions, provides appreciation, conveys the next agenda, and closes the lesson	22, 23, 24, 25

The student activity observation sheet in this study was designed to assess the implementation of learning activities using game-based outdoor learning. The observation sheet was used during the learning activities by checking the statements in the appropriate columns based on a rating scale with the following scores:

1 : Not implemented
2 : Partially implemented
3 : Moderately implemented
4 : Well implemented

Table 4. Blueprint of the Student Activity Observation Sheet for Game-Based Outdoor Learning

Steps	Observed Aspect	Item
	Preliminary Activities	
Orientation	Students respond to the teacher's greeting	1
	Students pray, led by the class leader	2

	Students take turns confirming their attendance by raising their hands when their names are called	3
	Students pay attention to the teacher's explanation regarding the topic and material to be studied	4
Aperception	Students actively recall prerequisite material	5
Motivation	Students listen and respond to the teacher's motivation	6
Providing	Students pay attention to the explanation of learning objectives and strategies	7
Reference	Students form groups, listen to the game instructions, understand the worksheet (LKPD), and answer questions competitively	8, 9, 10, 11
	Main Activities	
Implementation	Students go to the designated location and complete each mission on the worksheet (LKPD)	12, 13, 14
Follow-up	Students present in groups and summarize the lesson	15, 16, 17, 18, 19
	Closing Activities	
Closure	Students share opinions, receive appreciation from the teacher, pay attention to the teacher's final remarks, and close the lesson, menyimak apa yang disampaikan guru dan menutup pembelajaran	20, 21, 22, 23

Data Collection

Data collection in this study was conducted over a period of three weeks, comprising six meetings in total. In the first meeting, the researcher administered a pretest to measure students' mathematical spatial ability before the outdoor learning activities. From the second to the fifth meeting, the researcher conducted the treatment for the experimental class, which had previously taken the pretest, by implementing game-based outdoor learning using the learning materials that had been prepared in advance. In the sixth meeting, the researcher administered a posttest to measure students' mathematical spatial ability after participating in the game-based outdoor learning activities. According to Husamah (2013), outdoor learning consists of three stages: the preparation stage, the implementation stage, and the follow-up stage. During the preparation stage, the teacher determines the expected learning objectives for students, particularly related to using the environment as a learning medium and resource. The teacher selects the objects to be studied or visited, considering the relevance to the learning objectives, determines how students will engage in learning during the visit, and prepares the technical aspects of the learning activities, such as rules of conduct during the trip and at the destination, required learning equipment, and other preparations. The game mechanism used during the learning activities is as follows:

1. The teacher prepares worksheets (LKPD), measuring tools (ruler/tape measure), cardboard, and papers with images of three-dimensional objects.
2. The initial activity is conducted in the classroom, where each group identifies the shapes of objects from the images. Groups that answer correctly receive 1 star.
3. In groups, students move outside the classroom to the designated location.
4. Each group must complete three main missions outside the classroom:
   - **Mission 1:** Observe the shapes
   - **Mission 2:** Measure and record
   - **Mission 3:** Construct nets of the objects

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5. After the allocated time, all groups return to the classroom.
6. Each group presents the results of their group discussion.
7. Each mission successfully completed is awarded 1 star.
8. The teacher determines the winning group based on the highest number of stars.
9. The session concludes with reflection and closing activities.

In the final stage, the follow-up stage, the teacher and students continue learning activities in the classroom to discuss and review the learning outcomes obtained from the outdoor environment. Each group is asked to report their results through presentations for class discussion, and students, together with the teacher, summarize the material learned and relate it to the subject matter. After the game-based outdoor learning activities have been conducted according to the planned stages, in the sixth or final meeting, students are administered a posttest to measure their mathematical spatial ability following four sessions of the outdoor learning intervention.

Data analysis

The data analysis techniques in this study were adjusted to the type of data obtained, namely the observation data on the implementation of learning activities and the students' mathematical spatial ability test data. The observation data were used to describe the process of implementing game-based outdoor learning, while the test data were used to determine the improvement in students' mathematical spatial ability after participating in the learning activities. The observation sheets were completed by the observer by checking each indicator according to the predetermined rating scale. The analysis of the observation data aimed to ensure that the learning process was carried out effectively and that students were actively engaged during the activities. The observation data were not used to test the research hypothesis; rather, they served as supporting data to strengthen the interpretation of the results from the mathematical spatial ability tests. Effective implementation of learning and high student activity were considered indicators that the learning conditions facilitated the development of students' mathematical spatial ability. Meanwhile, the students' mathematical spatial ability test data, consisting of pretest and posttest scores, were analyzed using descriptive statistics and N-gain analysis. The descriptive statistical analysis included calculating the minimum score, maximum score, mean score, and standard deviation. To determine the level of improvement in students' mathematical spatial ability, N-gain analysis was employed. The N-gain was calculated by comparing the difference between pretest and posttest scores. The resulting N-gain values were then interpreted into categories of high, medium, or low improvement. This analysis served as the basis for testing the research hypothesis, namely that there is an improvement in students' mathematical spatial ability.

Results

This study aimed to examine how the implementation of game-based outdoor learning could improve students' mathematical spatial ability, particularly in the topic of polyhedra with flat faces. The research findings were obtained through the analysis of observation data on the implementation of learning activities by teachers and students, as well as students' mathematical spatial ability test data. The data were analyzed based on the spatial ability indicators proposed by Maier (1998).

Implementation of Game-Based Outdoor Learning

This study was conducted at SMP Negeri 9 Kota Jambi during the odd semester of the 2025/2026 academic year. The researcher used only one experimental class, which was selected randomly. The class chosen for the study was Class IX B. In this class, lessons were delivered using game-based outdoor learning. The outdoor learning was conducted in three stages: the preparation stage, the implementation stage, and the follow-up stage.

During the preparation stage, the teacher determined the learning objectives, namely that students would be able to construct nets of three-dimensional objects (prisms and pyramids) and create three-dimensional objects (prisms and pyramids) from their nets. Next, the teacher selected the objects to be studied or visited, including iron fences, garden ornaments, storage containers, and traditional cakes. The teacher also prepared the technical aspects of the learning activity, including the game rules, game mechanisms, worksheets (LKPD), and the required tools and materials to be brought by the students.

During the implementation stage, the teacher guided the students to carry out learning activities at the designated locations according to the prepared plan. The students observed and examined the objects being studied, and, in their groups, completed each mission on the worksheet (LKPD) to earn stars.

Figure 2. Mission 1: Identifying Three-Dimensional Objects

In Mission 1, students conducted observations to identify whether the objects were triangular prisms, triangular pyramids, rectangular prisms, or rectangular pyramids. In this activity, students were able to develop their spatial abilities, namely spatial perception and spatial orientation, as they learned to recognize the shapes and characteristics of three-dimensional objects in the environment and determine the objects' positions from different perspectives.

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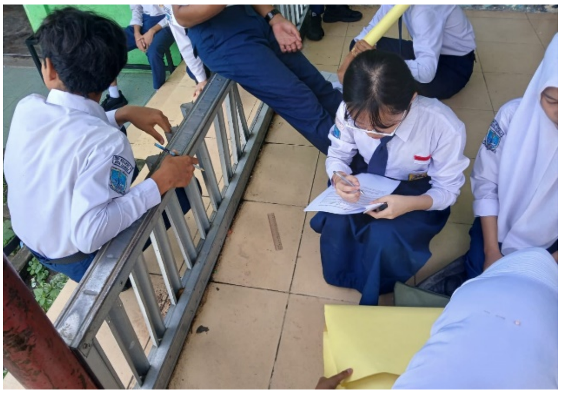

Figure 3. Mission 2: Measuring Objects and Recording the Results

In Mission 2, students measured the objects and recorded the results on the worksheet (LKPD). In this activity, students were able to develop their spatial abilities, specifically spatial perception and spatial relations, as they learned to understand real-world measurements and spatial proportions, and built an understanding of the relationships between dimensions (height, length, and width).

Figure 4. Mission 3: Constructing Nets of Three-Dimensional Objects Based on Measurement Results

In Mission 3, students constructed nets of three-dimensional objects based on their previous measurements. In this activity, students were able to develop their spatial abilities, specifically spatial visualization and mental rotation, as they learned to imagine folding the nets and mentally rotate the shapes to check whether the sides fit correctly. Next, in the follow-up stage, the teacher and students continued the learning activities in the classroom to discuss and review the learning outcomes obtained from the outdoor environment. Each group was asked to present their results for class discussion, and students, together with the teacher, summarized the material learned and connected it to the relevant subject matter.

Figure 5. Students Give Presentations

The teacher awarded stars to each group that completed the missions quickly and accurately. At the end of the learning activity, the teacher counted the total number of stars obtained by each group and then determined the winning group based on the highest number of stars earned.

Figure 6. The Group with the Most Stars as the Game Winner

Results of the Observation Sheets on the Implementation of Game-Based Outdoor Learning

Direct observation of the implementation of learning by the teacher in the classroom was conducted by an observer during the game-based outdoor learning activities. The observation sheet was completed by a single observer, who was a colleague of the researcher. The observer filled out the sheet by placing a check mark in the column corresponding to each statement based on the rating scale, with the following scores:

1 : Not implemented
2 : Partially implemented
3 : Moderately implemented
4 : Well implemented

The percentage of learning implementation could then be calculated using the following formula:

$$\boldsymbol{P} = \frac{\boldsymbol{F}}{\boldsymbol{N}} \times \mathbf{100\%}$$

Note:
P : Percentage of learning implementation

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F : Total score of learning implementation

N : Maximum possible score of learning implementation (maximum score × number of items)

The classification of the percentage of learning implementation can be seen in the Table 5.

Table 5. Classification of the Percentage of Learning Implementation by Teachers and Students

Interpretation	Criteria
$90\% < P \leq 100\%$	Very Good
$75\% < P \leq 90\%$	Good
$60\% < P \leq 75\%$	Fairly Good
$40\% < P \leq 60\%$	Not Good
$0\% \leq P \leq 40\%$	Very Poor

Source: Ramadhana & Hadi (2021)

The following is a summary of the observation results on the implementation of game-based outdoor learning by the teacher.

Table 6. Summary of Teacher's Implementation Observations in Outdoor Game-Based Learning

Description	Average Implementation Percentage per Meeting				Average (%)
	1	2	3	4	
Average (%)	93	91	93	91	92
Criteria	Very Good				Very Good

Based on the summary of the observation sheets on the implementation of learning by the teacher, it was found that the average percentage of learning implementation by the teacher during the first and third sessions was 93%, while during the second and fourth sessions it was 91%. According to Ramadhana & Hadi (2022), if the percentage of learning implementation falls within the range of 90% < P ≤ 100%, it is categorized as very good. This indicates that the teacher's implementation of learning in the classroom over the four sessions was carried out very effectively.

Similarly, direct observations of student learning activities in the classroom were conducted by an observer during the game-based outdoor learning process. The following is a summary of the observation results of student activities during the game-based outdoor learning sessions.

Table 7. Summary of Student Activity Observations During Outdoor Game-Based Learning

Description	Average Implementation Percentage per Meeting				Average (%)
	1	2	3	4	
Average (%)	89,13	90,21	90,21	89,13	89,67
Criteria	Good	Very Good	Very Good	Good	Good

Based on the summary of the observation sheets on student activity, it was found that the average percentage of implementation during the first and fourth sessions was 89.13%, while during the second and third sessions it was 90.21%. According to Ramadhana & Hadi (2022), if the percentage of learning implementation falls within the range of 90% < P ≤ 100%, it is categorized as very good, and if it falls within 75% < P ≤ 90%, it is categorized as good. This indicates that student learning activities in the classroom over the four sessions were carried out effectively.

Results of Students' Mathematical Spatial Ability Tests

In this study, the mathematical spatial ability test was administered to 28 students of Class IX B after participating in the game-based outdoor learning sessions. The test consisted of four items representing five spatial ability indicators: spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation.

Spatial Ability Indicator: Spatial Perception

For the spatial perception indicator, students were able to identify spatial figures placed in horizontal or vertical positions from different perspectives. The following are examples of student responses that met the spatial perception indicator for item number 1.

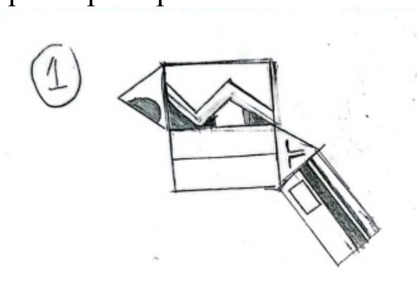

Figure 7. Student Responses Meeting the Spatial Perception Indicator

Spatial Ability Indicator: Spatial Visualization

For the spatial visualization indicator, students were able to visualize the actual shape of a three-dimensional object and determine its position after manipulation. The following are examples of student responses that met the spatial visualization indicator for item number 2.

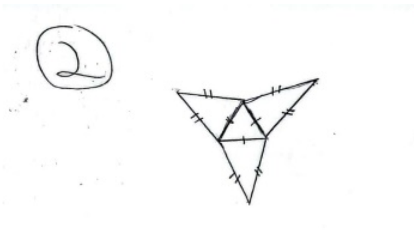

Figure 8. Student Responses Meeting the Spatial Visualization Indicator

Spatial Ability Indicator: Mental Rotation

For the mental rotation indicator, students were able to identify vertices and distances between points on a three-dimensional object after it was rotated. The following are examples of student responses that met the mental rotation indicator for item number 3.a.

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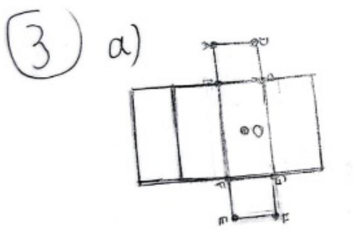

Figure 9. Student Responses Meeting the Mental Rotation Indicator

Spatial Ability Indicator: Spatial Relations

For the spatial relations indicator, students were able to determine the distances or relationships between points, lines, and planes in space. The following are examples of student responses that met the spatial relations indicator for item number 3.b.

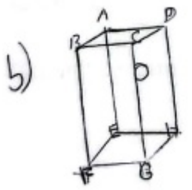

Figure 10. Student Responses Meeting the Spatial Relation Indicator

Spatial Ability Indicator: Spatial Orientation

For the spatial orientation indicator, students were able to visualize and draw the shape of a three-dimensional object from a specific viewpoint. The following are examples of student responses that met the spatial orientation indicator for item number 4.

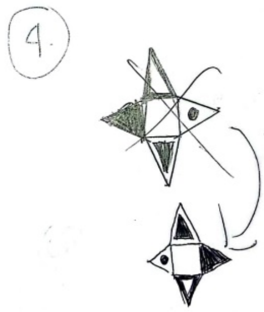

Figure 11. Student Responses Meeting the Spatial Orientation Indicator

The data from the students' mathematical spatial ability tests were further analyzed using descriptive statistics and N-gain calculations to examine the improvement in students' abilities. The following presents the results of the analysis of mathematical spatial ability test data for Class IX B at SMP Negeri 9 Kota Jambi. Descriptive statistical analysis of this variable was conducted to provide an overall Figure of the data. In this study, the mean, maximum, minimum, and standard deviation of students' mathematical spatial abilities were calculated. The results of the descriptive statistical analysis can be seen in Table 8.

Table 8. Descriptive Statistics Results

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Mathematical Spatial Ability	28	20.00	86.60	56.6357	17.44458
Valid N (listwise)	28				

Source: Output *IBM SPSS Statistics*

Based on the descriptive statistical analysis above, the distribution of the data obtained by the researcher shows that the students' mathematical spatial abilities can be described as follows: the minimum score was 20, the maximum score was 86.6, the mean score was 56.6357, and the standard deviation was 17.44458. Based on the N-Gain calculation according to Ramadhana & Hadi (2021), an improvement in students' mathematical spatial abilities was observed after participating in game-based outdoor learning. The criteria for high, medium, and low improvement are presented in the following Table 9.

Table 9. Students' N-Gain Scores

N-Gain Category	Frequency	Percentage
High	3	11%
Moderate	20	71%
Low	5	18%
Total	***28***	***100%***

Discussion

The results of this study indicate that the implementation of game-based outdoor learning has a significant impact on improving students' mathematical spatial abilities in the topic of three-dimensional shapes with flat faces. This finding aligns with previous research that aimed to enhance learning through innovations in both learning environments and methods (Crismono, 2023). The use of games also serves to motivate students in the learning process. This is consistent with the findings of Prasetiyo et al. (2023), which suggest that outdoor learning combined with game-based activities can stimulate problem-solving skills, be effectively applied in the learning process, and encourage the generation of new ideas from students.

This study demonstrates that game-based outdoor learning can enhance students' spatial abilities, particularly their ability to understand nets of three-dimensional shapes through real-world learning experiences outside the classroom. This is in line with the findings of Yumiati et al. (2023), which highlight that outdoor game-based learning is not merely an innovation in learning activities but is also effective in developing mathematical spatial abilities because it involves direct student engagement with real-world contexts. Furthermore, this study assessed the effectiveness of outdoor learning on students' mathematical spatial abilities, showing that outdoor learning led to a significant improvement in spatial skills after the field-based treatment. The findings of Amaluddin et al. (2019) provide empirical evidence that well-structured and properly designed outdoor learning is effective for students, reinforcing the theory that real-world experiences strengthen spatial skills.

Based on the data obtained, most students showed a moderate improvement in spatial abilities. This indicates that the implementation of outdoor learning in mathematics allows students to think critically and develop their spatial thinking skills (Puteri & Mariana, 2024). This is also influenced by direct learning experiences with real objects in their surroundings,

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which promote deeper understanding compared to merely observing images. Therefore, outdoor learning provides a stimulating and contextual environment for the development of students' spatial intelligence (Harahap et al., 2023).

Game-based outdoor learning has a positive impact on the development of students' mathematical spatial abilities across all indicators proposed by Maier (1998), namely spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation. Through direct observation of real objects in their environment, students become more capable of recognizing the positions and locations of objects both horizontally and vertically (spatial perception). Game activities that involve the representation and transformation of three-dimensional shapes encourage students to mentally imagine changes in shape (spatial visualization), while simultaneously training them to rotate objects accurately from various perspectives (mental rotation). In addition, students' interaction with objects and group discussions during learning help them understand the relationships between parts of a shape and the connections between objects (spatial relations). Opportunities to observe objects from different positions during outdoor activities also strengthen students' ability to determine the direction and orientation of objects in space (spatial orientation).

The novelty of this study lies in the use of games within outdoor learning. Games with clear rules can make the learning process more structured and have a positive effect on improving students' spatial abilities (Kurnila et al., 2019). This finding aligns with the study by Mahendra et al. (2024), which suggests that game-based learning can increase students' motivation by creating an interactive and enjoyable learning environment. Overall, this study confirms that the implementation of game-based outdoor learning allows students to gain direct experiences with real-world objects and creates an enjoyable learning atmosphere through games. This, in turn, positively influences students' mathematical spatial abilities in the topic of three-dimensional shapes with flat faces.

Conclusion

The results of this study indicate that students' mathematical spatial abilities improved after the implementation of game-based outdoor learning on the topic of three-dimensional shapes with flat faces. Among the 28 students, 3 students showed high improvement, 20 students showed moderate improvement, and 5 students showed low improvement based on N-gain calculations. These findings suggest that game-based outdoor learning has the potential to serve as an alternative strategy for teaching geometry to support the development of students' spatial abilities. This study contributes to the implementation of outdoor learning that utilizes the surrounding environment and structured games as a relevant context for learning activities. The limitations of this study include constraints in outdoor space/location, which affected the focus of some students, and the use of a one-group design without a control class, meaning that the improvement cannot be fully attributed solely to the treatment. Future research should involve a control class, expand the location or activity settings, apply the approach to other topics, and analyze improvements in each spatial ability indicator.

Conflict of Interest

The authors declare that this article was prepared as part of fulfilling the requirements for the completion of a student's final project. Aside from this purpose, there are no other conflicts of interest that influenced the planning, implementation, analysis, or writing of the research results.

Authors' Contributions

I.N.R. actively participated in the implementation, data collection, preparation of instruments, article narrative, discussion of results, and editing of the manuscript for the final version. S. and K.A. contributed to understanding the main research ideas, theoretical development, methodology, data organization and analysis, discussion of results, and approval of the final version of the manuscript. All authors confirm that they have read and approved the final version of this paper. The total percentage of contribution to conceptualization, writing, and manuscript revision is as follows: I.N.R.: 40%, S.: 30%, and K.A.: 30%.

Data Availability Statement

The authors declare that data sharing is not applicable, as no new data were created or analyzed in this study.

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