

RESEARCH ARTICLE

Fostering Spatial Thinking Ability through Problem-Based Learning: Evidence from Senior High School Geography Education

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ABSTRACT

This study aims to examine how the implementation of the Problem Based Learning (PBL) model affects the spatial thinking ability of eleventh-grade students on disaster mitigation material at SMA Negeri 1 Pringsewu. The background of this study is the low spatial thinking skills of students in understanding disaster concepts and effective mitigation strategies, which necessitates attention to improving these skills in geography learning. The research method used a quantitative approach with a quasi-experiment and a non-equivalent control group design. The sample consisted of two classes: an experimental class using the PBL model and a control class receiving conventional learning. Data were collected through a spatial thinking test that had been validated and tested for reliability, and then analyzed using a t-test with SPSS. The results showed a significant difference in spatial thinking ability between students taught using the PBL model and those taught conventionally. The significance value (Sig. 2-tailed) of 0.000 (<0.05) indicates that the PBL model positively affects the spatial thinking ability of eleventh-grade students at SMA Negeri 1 Pringsewu. This study is expected to contribute to improving geography learning quality by strengthening the understanding of disaster mitigation through the development of spatial thinking skills.

Keywords: learning model, Problem Based Learning, spatial thinking



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1. INTRODUCTION

In facing the rapid advancement of science and technology, students need to possess appropriate spatial thinking competencies in order to compete in this modern era. Students who have spatial abilities demonstrate specific characteristics, namely understanding direction, carrying out thinking processes, and utilizing three-dimensional perspectives to design something (Badan Informasi Geospasial, 2015). In the context of spatial thinking, students must develop visualization skills, spatial analysis, and problem-solving abilities related to space and form to effectively support the learning process.

Students' spatial thinking ability is a set of cognitive skills that encompasses a combination of three elements: spatial concepts, representation, and thinking processes (Faizah, 2016). Spatial thinking skills

can help students understand how geography learning integrates fundamental spatial concepts into research (Aliman, 2016). This ability enables students to observe, analyze, describe, and make decisions about various aspects, ranging from simple to complex matters, such as location, distance, direction, and estimated travel time.

Current classroom realities indicate that most learning activities remain teacher-centered, where the teacher is regarded as the sole source of information and students merely act as recipients during the learning process. As a result, students tend to appear passive, and classroom participation is often dominated by only a few active students. This situation leads to boredom and a lack of attention to the lesson. Moreover, the assumption that geography is a memorization-based subject creates a passive and monotonous classroom environment, which consequently contributes to the poor development of students' spatial thinking skills (Kurniawati et al., 2023).

This study examines geography as a discipline that investigates physical and human phenomena on the Earth's surface and their interactions (Sahrina & Deffinika, 2021). Geography continuously explores the Earth and all its contents by analyzing both social and physical aspects and their interrelationships within an environmental context (Handayani, 2024). This statement indicates that geographical studies focus on spatial relationships. This is consistent with Hangget (1983), who stated that "Geography is an integrative discipline that brings together the physical and human dimensions of the world in the study of people, place, and environments" (Aksa et al., 2019). Geography as a subject supports the development of students' understanding of the relationships between geosphere phenomena and social aspects within a specific spatial context. This demonstrates that one of the objectives of geography education is to enhance students' spatial thinking abilities (Nurcahyo & Winanti, 2021), reduce students' misconceptions, and improve their conceptual understanding.

Based on the results of the preliminary observation, it was found that the daily test scores in Geography for the disaster mitigation material in Grade XI at SMA N 1 Pringsewu in the 2023/2024 academic year were relatively low. Among classes XI F.1 and XI F.10, only 11 students in class XI F.1 and 13 students in class XI F.10 achieved scores above the Minimum Completeness Criteria (KKTP) of 78. It can therefore be stated that less than 50% of the students in those classes were able to adequately understand the material. This finding is supported by the preliminary observation results from the geography teacher, who stated that spatial concepts had not yet been implemented in the disaster mitigation material. Consequently, there is a need to enhance students' spatial thinking skills to support the spatial concepts embedded in disaster mitigation content. Therefore, innovation in teaching methods is required to improve students' understanding of the subject matter (Zendrato et al., 2024). Considering that SMA N 1 Pringsewu is regarded as one of the leading senior high schools in Lampung Province and is known as "the school of champions," students' spatial thinking abilities need to be further strengthened.

In another context, Pringsewu Regency is one of the regions in Lampung Province that is considered prone to flooding. This natural disaster consistently occurs during the rainy season (Cahyani et al., 2020). As a flood-prone area, Pringsewu Regency highlights the importance of understanding spatial concepts, particularly for students. Through spatial knowledge, students can analyze various contributing factors to flooding, such as rainfall intensity, elevation, soil type, land cover, and slope gradient. This understanding enables them to examine and propose relevant solutions to mitigate disaster impacts.

Learning activities at SMA N 1 Pringsewu need to adapt to the demands of instructional materials. One strategic step that can be taken is transforming the learning process by implementing an instructional model that aligns with the subject matter. Such a model is expected to enhance students' spatial thinking skills in understanding and solving problems related to space and form. Since spatial thinking skills should be cultivated from an early stage, they can be developed through learning activities that encourage exploration, inquiry, discovery, and problem-solving. These activities may be conducted individually or in small groups, allowing students to discuss and exchange perspectives on the spatial concepts they learn. Ultimately, the development of spatial thinking skills will assist students in understanding their environment and making appropriate decisions based on sound spatial analysis.

The implementation of a learning model that can foster spatial thinking skills is Problem-Based Learning (PBL). In line with previous research conducted by (Ningrum & Perkasa, 2024) regarding the implementation of the Problem-Based Learning model to enhance the spatial thinking skills of Grade X students at SMAN 13 Samarinda, the findings indicate that the application of the PBL model has a significant effect on improving students' spatial thinking abilities. This improvement can be observed from the pre-test and post-test results in the experimental class, where several spatial thinking indicators—comparison, transition, pattern, and association—showed significant enhancement after the implementation of PBL.

This implies that problem-based learning is an effective approach to encourage the development and improvement of students' spatial thinking skills (Sasmita et al., 2015). The model offers several advantages in strengthening spatial thinking abilities. One of its strengths lies in its learning approach, which emphasizes students' active involvement in solving real-life problems, thereby helping them connect information visually and logically. Through this process, students are trained to observe, analyze, and organize information based on location, direction, and spatial relationships. This is highly relevant to spatial thinking, which requires the ability to understand relationships among objects within a given space. Therefore, the implementation of PBL not only reinforces conceptual understanding but also supports the development of skills in visualizing and interpreting spatial information more effectively.

Various studies have indeed demonstrated that the Problem-Based Learning (PBL) model can enhance students' spatial thinking skills. However, most of these studies have focused primarily on theoretical materials such as the atmosphere, geosphere, or geometry, and many have heavily relied on the use of specific digital media. Consequently, research on the application of PBL in disaster mitigation material remains limited, even though this topic requires contextual, location-based spatial thinking closely related to real-world conditions. Furthermore, previous studies generally employed the full eight spatial thinking indicators proposed by the American Association of Geographers (AAG), which are considered too broad and less operational for implementation at the senior high school level, resulting in less focused measurement. Therefore, this study addresses this gap by simplifying and adapting the AAG indicators in combination with the Bernaz & Lee framework into five main indicators that are more practical and relevant. These indicators are tested through a quantitative approach using a non-equivalent control group pretest-posttest design and analyzed using a t-test.

Thus, this study aims to (1) examine the implementation of the Problem-Based Learning model in map utilization material at SMA N 1 Pringsewu and (2) determine the effect of the Problem-Based Learning model on Grade XI students' spatial thinking skills in disaster mitigation material at SMA N 1 Pringsewu.

2. LITERATURE REVIEW

This section presents the theoretical foundations underlying the study, covering three main areas: (1) spatial thinking ability in geography education, (2) the Problem-Based Learning (PBL) model, and (3) the relationship between PBL and the development of spatial thinking skills. These theoretical frameworks provide the conceptual basis for understanding the research problem and for interpreting the findings of this study.

2.1 Spatial Thinking Ability in Geography Education

Spatial thinking is a fundamental cognitive competency in geography education that refers to the ability to conceptualize, analyze, and interpret objects and phenomena based on their location, distribution, and spatial relationships (National Research Council, 2006). Faizah (2016) described students' spatial thinking ability as a set of cognitive skills combining three elements: spatial concepts, representation, and reasoning processes. This ability enables students to observe, analyze, and make decisions about various aspects of space, from simple ones such as location and direction to complex ones such as the interpretation of spatial patterns. In the context of geography learning, Aliman (2016)

emphasized that spatial thinking helps students understand how geography integrates fundamental spatial concepts, enabling a more meaningful understanding of geographic phenomena.

The American Association of Geographers (AAG, 2008) and Bednarz & Lee (2019) have identified key spatial thinking indicators, including comparison, aura, region, understanding orientation and direction, and understanding spatial forms and patterns. These indicators require students to compare spatial data, recognize relationships among geographic phenomena, understand regional structures, and interpret geosphere distribution patterns. The importance of these skills in disaster mitigation learning has been highlighted by Sholikah (2023), who found that students' spatial thinking abilities significantly influence their understanding of disaster threat potential in specific regions. Despite this recognized importance, spatial thinking skills remain underdeveloped in many Indonesian high school students, largely due to teacher-centered instructional methods (Kurniawati et al., 2023).

2.2 Problem-Based Learning (PBL) as an Instructional Model

Problem-Based Learning (PBL) is a student-centered instructional approach in which students learn through the experience of solving real-world, open-ended problems. According to Sumarmi (2012), the PBL model consists of five main syntactic stages: (1) orienting students to the problem; (2) organizing students for learning; (3) guiding individual and group investigations; (4) developing and presenting the results; and (5) analyzing and evaluating the problem-solving process. Each stage is designed to promote higher-order thinking, independent inquiry, collaboration, and problem-solving based on real contexts.

The advantages of PBL lie in its emphasis on authentic problem contexts, which makes learning more meaningful and motivating for students (Nurchayyo & Winanti, 2021). Research has shown that PBL enhances collaboration skills (Ifada et al., 2024), fosters learning independence (Karimah & Pratama, 2025), and connects learning with real-world contexts (Sari & Darmayanti, 2024). In the geography context specifically, Buana & Putra (2023) confirmed that PBL implementation, whether through thematic maps or GIS-based digital media such as WebGIS Inarisk, can significantly improve students' ability to analyze spatially complex regions. These characteristics make PBL a highly relevant instructional approach for geography education, where learners must integrate physical, social, and spatial dimensions of knowledge.

2.3 The Relationship Between PBL and Spatial Thinking Ability

The relationship between PBL and spatial thinking ability is grounded in the alignment between the cognitive demands of PBL stages and the cognitive processes required for spatial reasoning. From the problem-orientation stage through investigation, students are confronted with spatial phenomena that require comparison, region, and aura abilities to analyze. Investigative activities make students interact directly with maps, diagrams, imagery, or other spatial data so that spatial thinking indicators are naturally trained and developed (Bednarz & Lee, 2019). Furthermore, the stages of presenting results and evaluation facilitate the ability to understand orientation, direction, shapes, and spatial patterns through the preparation of analytical work and reflection on solutions.

Empirical evidence supports this theoretical relationship. Ningrum & Perkasa (2024) found that the application of PBL had a significant effect on improving students' spatial thinking abilities, with notable improvements in the comparison, transition, pattern, and association indicators. Sasmita et al. (2015) similarly demonstrated that problem-based learning is an effective approach for the development of spatial thinking in geography. The research gap addressed by this study lies in the limited application of PBL specifically to disaster mitigation content, and the lack of studies that combine and simplify the AAG spatial thinking indicators with the Bednarz & Lee (2019) framework into a more operational and focused set for senior high school level in Indonesia.

3. METHOD

3.1 Design

The type of research employed in this study is quantitative research grounded in the philosophy of positivism, with statistical data analysis used to test predetermined hypotheses (Sugiyono in Abdullah et al., 2022). The research design applied is a quasi-experimental design of the non-equivalent control group type, which is a development of the true experimental design that is often difficult to implement in field settings. In this design, a control group is included; however, external variables that may influence the experiment cannot be fully controlled. This design involves two groups: an experimental group that receives treatment using the Problem-Based Learning model and a control group that is taught using conventional instruction (lecture method). A pretest and posttest are administered to both groups to determine differences in learning outcomes before and after the treatment.

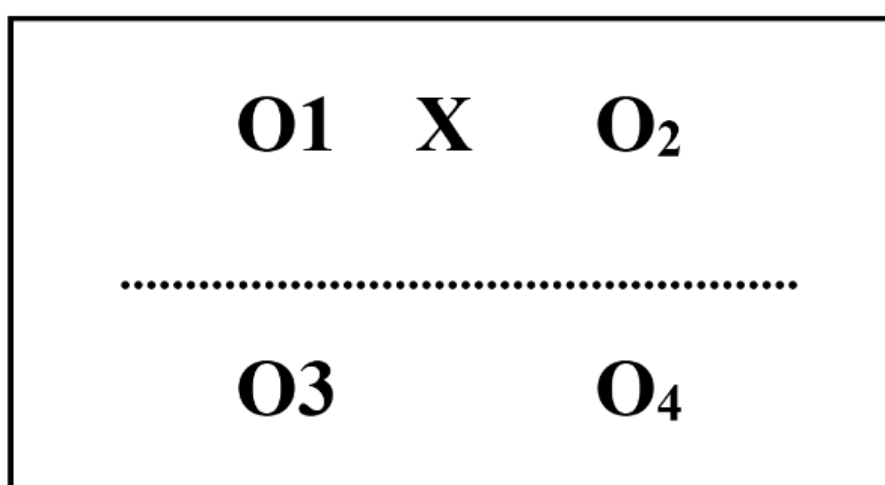


Figure 1. Research Design.

3.2 Research Location And Subjects

The study was conducted at SMA Negeri 1 Pringsewu, located at Jl. Olahraga No.1, Pringsewu Barat, Pringsewu Regency, Lampung, which is astronomically situated between 5°06'–5°15' South Latitude and 104°54'–105°06' East Longitude. The research population consisted of all Grade XI students majoring in Geography in the 2024/2025 academic year, totaling 144 students. The sampling technique employed was non-probability sampling using purposive sampling. Two classes were selected based on relatively comparable academic characteristics and lower average scores compared to other classes, namely XI.F1 as the control class and XI.F10 as the experimental class, each consisting of 36 students (a total of 72 students).

3.3 Research Instruments And Materials

The instruments used in this study included ArcGIS 10.8, SPSS version 24, mobile phones, instructional modules containing Student Worksheets (LKPD), as well as pretest and posttest sheets. The research materials consisted of data on the number of students, students' assessment scores, and pretest–posttest score data. The research instrument consisted of a 30-item multiple-choice test developed based on spatial thinking skill indicators and aligned with the basic competencies. The instrument included a pretest and a posttest administered to obtain data on students' spatial thinking abilities following the implementation of the Problem-Based Learning model. The spatial thinking indicators used in this study are presented systematically in tabular form.



Figure 2. Student Worksheet (LKPD)

Table 1. Spatial Thinking Indicators

Indicators	Sub-Indicators
Comparison	<ol style="list-style-type: none"> 1. Students are able to compare the effectiveness of disaster mitigation strategies in two regions with different characteristics. 2. Students are able to compare two regions experiencing different types of disasters.
Aura	<ol style="list-style-type: none"> 1. Students are able to explain the impact of mitigation efforts on surrounding areas and their influence on regional vulnerability. 2. Students are able to analyze the relationship between the location of a disaster epicenter and the affected areas using spatial data.
Region	<ol style="list-style-type: none"> 1. Students are able to classify areas prone to earthquakes and tsunamis. 2. Students are able to classify disaster-prone areas to examine local community adaptation using thematic maps.
Ability to Understand Orientation and Direction	<ol style="list-style-type: none"> 1. Students are able to identify disaster-prone locations on disaster potential maps or satellite imagery. 2. Students are able to evaluate whether a region has undergone a complete disaster mitigation cycle by analyzing the implemented mitigation indicators and considering their impact and effectiveness.
Ability to Understand Spatial Forms and Patterns	<ol style="list-style-type: none"> 1. Students are able to use topographic maps to understand the distribution patterns of areas with earthquake and tsunami potential.

3.4 Data Analysis

The data obtained were analyzed quantitatively. Descriptive analysis was employed to describe the mean scores, standard deviations, and the improvement in pretest and posttest scores for each group. Prior to hypothesis testing, prerequisite tests were conducted, including tests of normality and homogeneity. If the data were normally distributed and homogeneous, hypothesis testing was carried out using the independent samples t-test to compare the gain scores between the experimental and control groups. However, if the assumptions of normality or homogeneity were not met, a non-parametric alternative test, namely the Mann-Whitney U test, was applied.

4. RESULTS AND DISCUSSION

4.1 Pretest and Posttest Results

This study began with the administration of a pretest in both the control and experimental classes to evaluate students' initial spatial thinking abilities. The descriptive analysis of the pretest data presented in Figure 3 indicates that the mean scores of the experimental and control classes were at a comparable level. The median scores of both groups were also identical, suggesting that the central tendency of the data distribution between the two groups did not differ significantly. In addition, the mode in each class demonstrated nearly identical score frequencies. These findings indicate that the initial abilities of students in both the experimental and control classes were relatively homogeneous. Therefore, the baseline conditions of the two groups can be considered equivalent, allowing for a valid comparison after the research treatment was implemented.

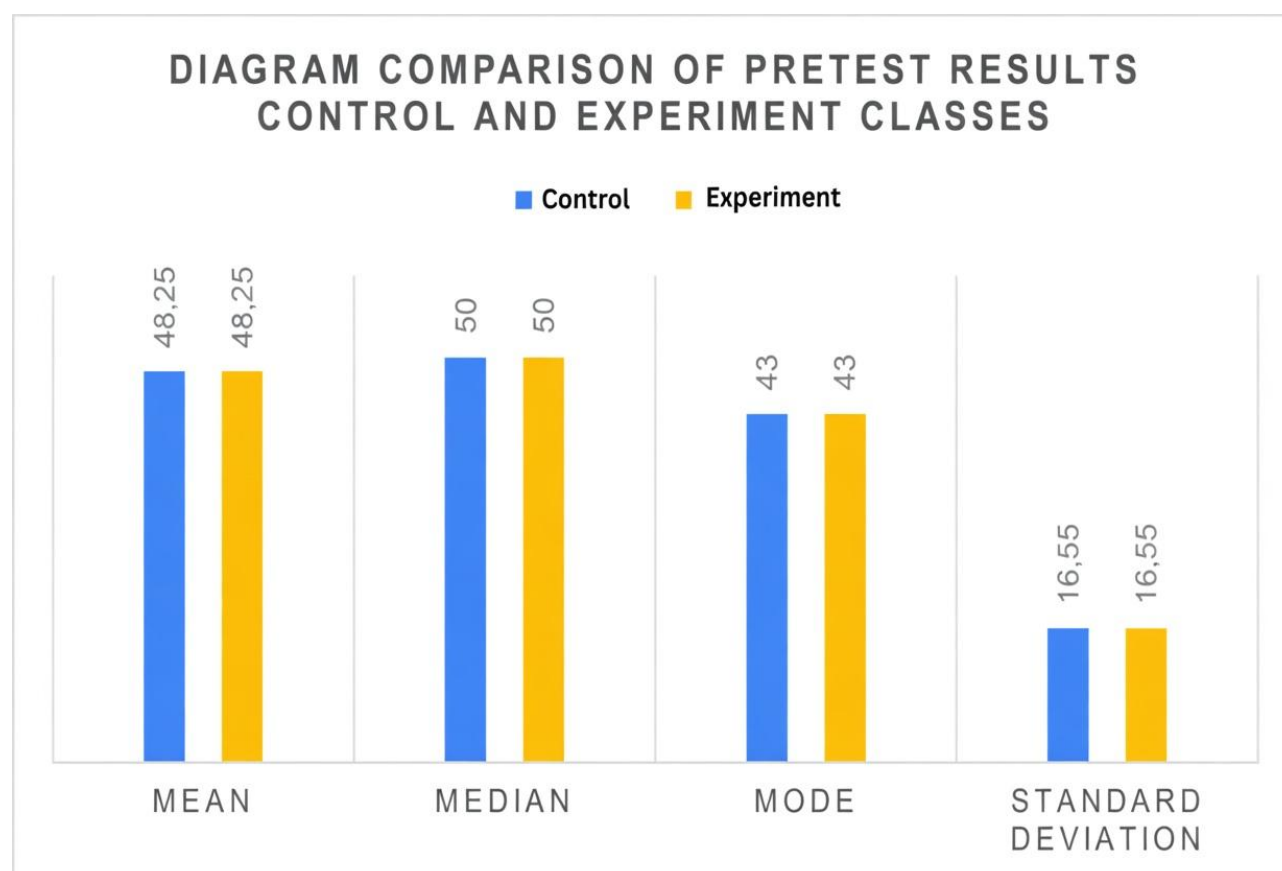


Figure 3. Comparison of Pretest Results Between the Control and Experimental Classes

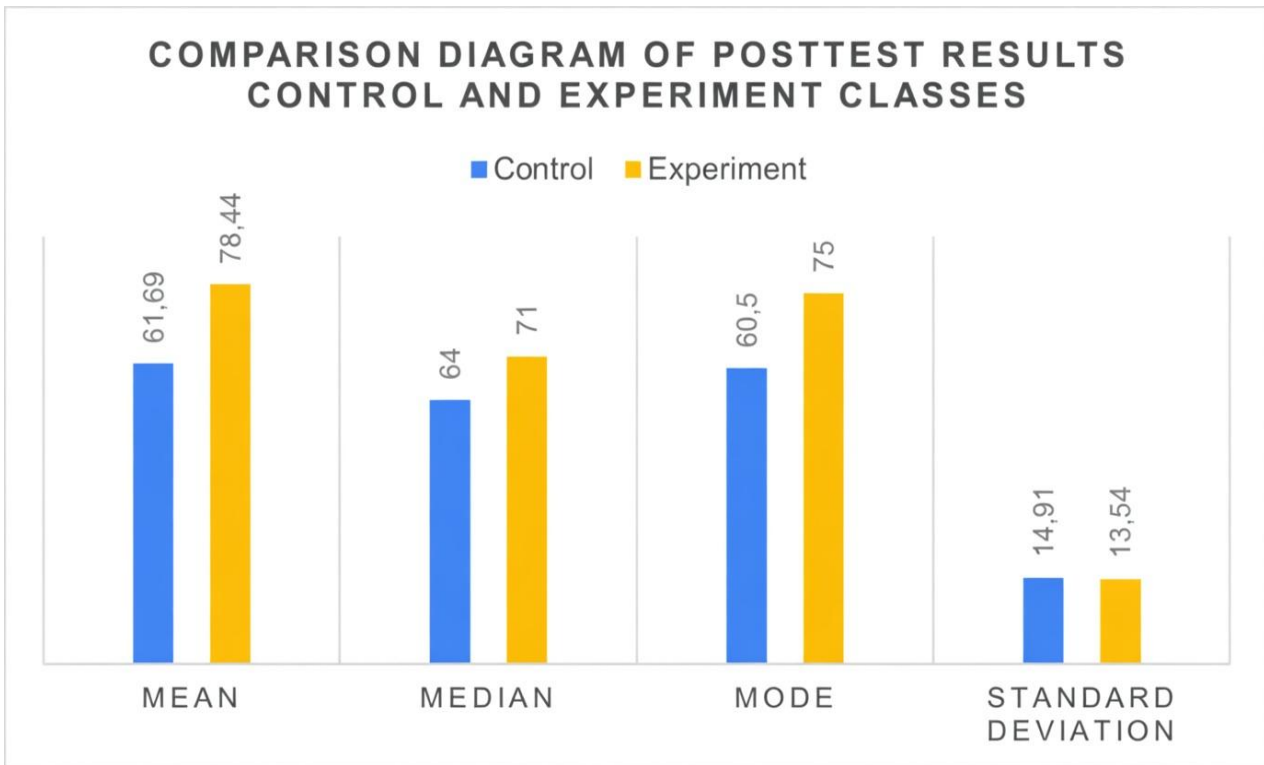


Figure 4. Comparison of Posttest Results Between the Control and Experimental Classes

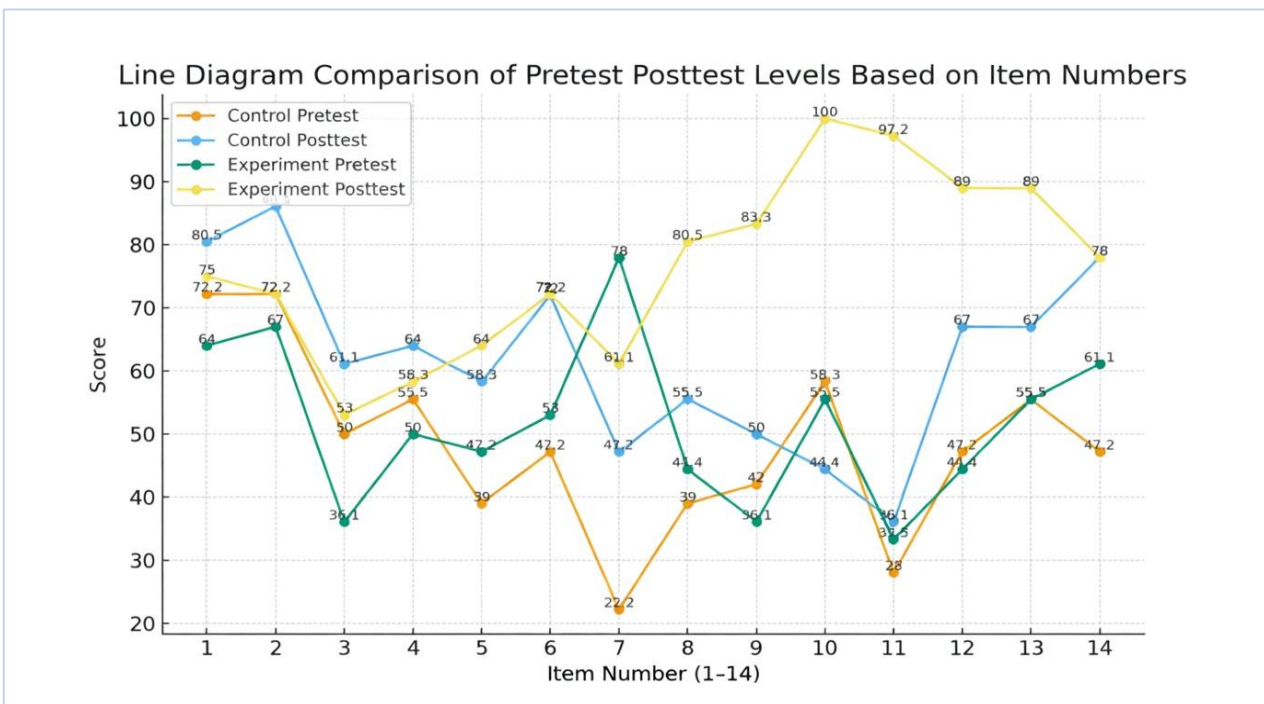


Figure 5. Line Graph Comparing Pretest and Posttest Scores by Item.

After both groups participated in learning activities using different instructional approaches, they completed a posttest to evaluate their learning outcomes. The data obtained indicate notable improvement, particularly in the experimental group. Based on the descriptive analysis of the posttest scores, it is evident that the experimental class taught using the Problem-Based Learning (PBL) model achieved better results compared to the control class. The mean score in the experimental class was 78.44, substantially higher than that of the control class, which reached only 61.69. This finding indicates

an overall improvement in students' spatial thinking abilities in the class that implemented PBL. The median score in the experimental class was 71, higher than the control class median of 64, suggesting that the majority of students in the experimental class achieved better performance. Furthermore, the mode values in the experimental class (71 and 79) indicate that many students attained scores within the higher range, whereas the control class modes (57 and 64) reflect lower performance levels. Overall, these results reinforce that the implementation of PBL has a positive impact on students' spatial thinking skills compared to traditional instructional methods.

Based on Figure 5, which illustrates the comparison of pretest and posttest scores for each test item, differences in the pattern of improvement in spatial thinking skills between the control and experimental classes are evident. In the control class, posttest scores showed improvement on most items, for example, item 1 increased from 72.2 to 80.5, item 2 from 72.2 to 86.1, and item 6 from 47.2 to 72. The improvement was moderate and relatively stable, indicating that conventional instruction primarily reinforced students' basic abilities without producing substantial changes in spatial understanding.

In contrast, the experimental class demonstrated a much sharper increase in scores across nearly all test items. This is particularly evident in several items that showed significant gains, such as item 8, which increased from 44.4 to 80.5; item 9, from 36.1 to 83.3; item 10, from 55.5 to 100; and item 11, from 33.3 to 97.2. These substantial improvements indicate that students in the experimental class experienced stronger and more comprehensive development of spatial understanding compared to those in the control class.

Overall, the trend lines in the graph reveal that score improvements in the control class were relatively gradual, with minimal variation across items, whereas the experimental class exhibited steeper slopes, indicating more intensive enhancement of spatial thinking skills. This difference in improvement patterns suggests that the implementation of the Problem-Based Learning (PBL) model had a greater impact on students' spatial thinking abilities. Through the structured stages of PBL—problem identification, independent investigation, data analysis, and presentation of findings—students were able to develop spatial reasoning more optimally. Thus, the line graph in Figure 5 reinforces the finding that the PBL model is effective in improving spatial thinking skills, particularly on items requiring higher-order cognitive processes, compared to conventional instruction, which demonstrated relatively limited improvement.

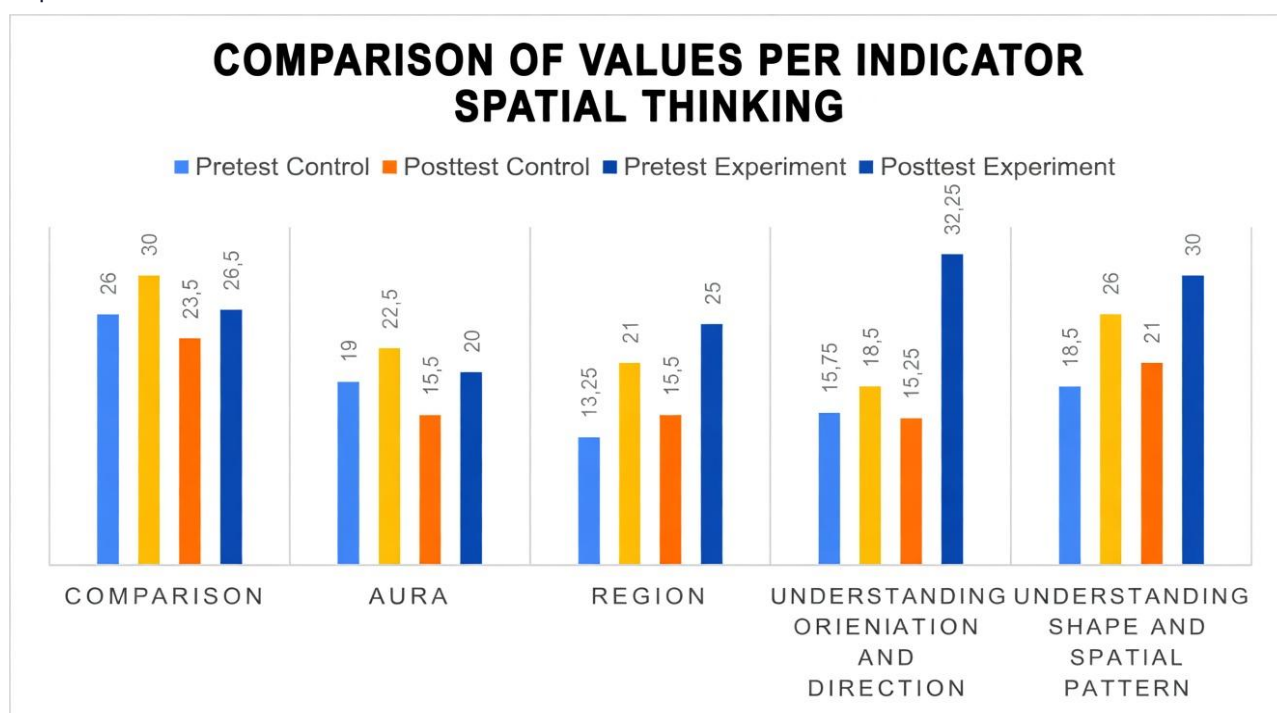


Figure 6. Bar Chart Comparing Scores by Students' Spatial Thinking Indicators.

These findings also support the study conducted by Ningrum and Perkasa (2024), which reported that the PBL model is more effective in enhancing spatial thinking skills compared to other instructional methods, particularly in indicators such as transition, pattern, and association. Therefore, this study not only strengthens previous findings but also incorporates additional indicators, providing a more comprehensive perspective on the effectiveness of PBL in developing students' spatial thinking skills. The results indicate that students were able to analyze each test item effectively and meet the mastery criteria across all spatial thinking indicators. Supporting data for this statement are presented in Figure 6.

Based on Figure 6, which presents a comparison of the mean scores across the five spatial thinking indicators, a noticeable difference in improvement between the control and experimental classes can be observed. In the control class, all indicators showed an increase from pretest to posttest, although the improvements were generally moderate. The highest increase was observed in the region indicator, which rose from 13.25 to 21, followed by the spatial forms and patterns indicator, which increased from 18.5 to 26. These findings suggest that conventional instruction was able to reinforce basic spatial thinking skills; however, it was not sufficient to significantly promote the development of more complex spatial abilities.

In contrast, the experimental class demonstrated substantially greater improvement across all indicators after the implementation of the Problem-Based Learning (PBL) model. The most significant increase was found in the understanding orientation and direction indicator, which rose markedly from 15.25 to 32.25. The region indicator also showed a strong improvement, increasing from 15.5 to 25. These substantial gains indicate that problem-based learning effectively activates students' abilities to comprehend spatial relationships, spatial navigation, and regional analysis more deeply.

Overall, the posttest scores of the experimental class were higher than those of the control class across all indicators. The most prominent difference was observed in the understanding orientation and direction indicator, highlighting the effectiveness of PBL in enhancing students' abilities to determine position, direction, and spatial relationships among geographic objects or phenomena. This finding aligns with the characteristics of PBL, which emphasize inquiry activities, problem-solving processes, and the exploration of spatial data, thereby actively engaging students in spatial reasoning.

Thus, the bar chart in Figure 6 provides visual evidence that reinforces the statistical test results, demonstrating that the Problem-Based Learning model significantly contributes to the improvement of Grade XI students' spatial thinking skills. PBL not only increased the mean scores across all indicators but also produced more substantial improvements compared to conventional instruction, particularly in orientation and regional analysis skills. Additional supporting evidence can also be explained through the results of the student worksheets (LKPD) completed by the students, as discussed below.

In the first indicator, namely comparison, students demonstrated achievement in analyzing and comparing differences between two regions with distinct causal factors, which consequently resulted in variations in the level of disaster damage. Through this process, students were able to understand the various factors influencing risk and how each region responds to disasters. This ability aligns with the findings of Amelia and Febriandi (2024), who revealed that students' understanding and skills in mitigating disaster impacts improved when they were able to analyze differences in conditions between affected regions and evaluate the effectiveness of the response strategies implemented. In the learning process, students were not only able to identify disaster-triggering factors but also to compare varying levels of damage and responses across regions, enabling them to provide a more comprehensive assessment of the geographical and social conditions influencing disaster risk.

The second indicator, namely aura, also showed successful attainment. Students demonstrated the ability to analyze the relationship between the location of a disaster epicenter and the affected areas using spatial data accurately. They were able to recognize patterns in the distribution of disaster impacts based on distance and regional characteristics, thereby providing a clear and comprehensive understanding of how the position of the disaster epicenter relates to the vulnerability level of impacted areas. Supporting this perspective, Darmawan and Miswar (2022), in the *Jurnal Penelitian Geografi*,

utilized Geographic Information Systems (GIS) to evaluate disaster-prone areas by considering spatial variables such as contour lines, slope gradients, land use types, and distance from the hazard source. Their findings indicate that the relationship between the disaster epicenter location and regional vulnerability levels can be effectively understood through spatial analysis.

The next indicator, region, also demonstrated that students achieved mastery in spatial thinking skills, as evidenced by their ability to classify areas prone to earthquakes and floods. Furthermore, students were able to utilize thematic maps effectively to identify and categorize disaster-prone regions accurately. This finding is consistent with the study conducted by Buana and Putra (2023), which reported that the implementation of Problem-Based Learning (PBL) enhances students' ability to analyze and classify regions based on spatial characteristics. The implementation of Problem-Based Learning (PBL) supported by the WebGIS Inarisk platform has been proven effective in enhancing students' spatial thinking skills, particularly in understanding the distribution of disaster risk and mitigation strategies. This finding indicates that PBL, whether implemented using thematic maps or GIS-based digital media, can significantly improve students' ability to analyze regions potentially affected by disasters.

Furthermore, in the indicator of understanding orientation and direction, students achieved mastery in spatial thinking skills. This was evident in their ability to analyze cardinal directions as references for identifying evacuation locations during disaster events, accurately utilizing disaster potential maps or satellite imagery. In addition, students were able to evaluate whether a region had undergone a complete disaster mitigation cycle by analyzing the mitigation indicators that had been implemented and considering the impact and effectiveness of these measures. This demonstrates that students were capable of providing comprehensive and in-depth assessments of regional preparedness and disaster-related conditions. This finding is consistent with Sholikah (2023), who reported that students' spatial thinking abilities significantly influence their understanding of disaster threat potential within their respective regions.

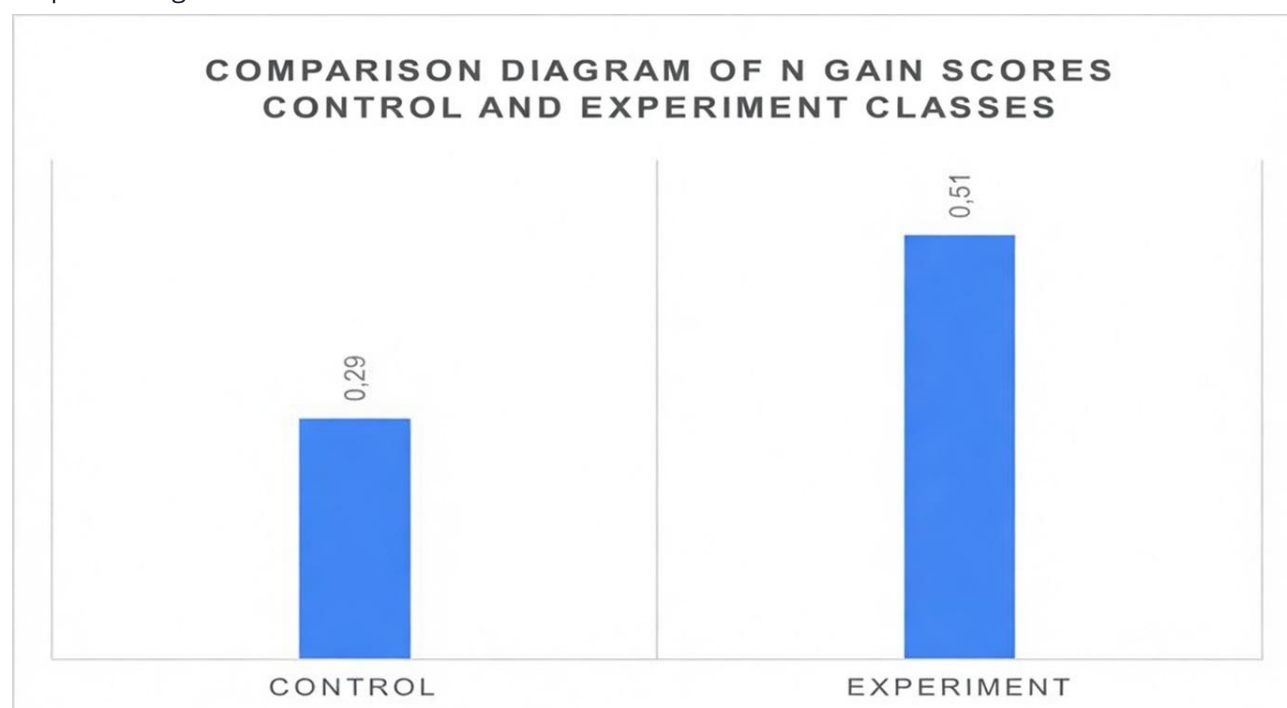


Figure 7. Comparison of N-Gain Scores Between the Control and Experimental Classes
(Source: Research findings, 2025)

Finally, in the indicator of understanding spatial forms and patterns, students successfully demonstrated spatial thinking skills by using topographic maps to understand and analyze the distribution of areas potentially affected by earthquakes and tsunamis. They were able to relate differences in contour lines and elevation on maps to varying levels of disaster vulnerability within a

region, thereby providing a clear depiction of high-risk areas. In line with this study, Sholikah (2023) revealed that students' spatial thinking abilities have a significant impact on their understanding of disaster threat potential in specific areas. This suggests that skills in processing and analyzing spatial information, such as maps, enhance students' comprehension of disaster risk distribution. In this context, students with stronger spatial thinking skills were also able to connect map elements with surrounding risk factors, resulting in a more comprehensive interpretation of earthquake and tsunami hazard-prone areas.

To evaluate learning progress, an N-Gain analysis was conducted. The results indicate that the mean N-Gain score for the control group was 0.29, which falls into the low category, whereas the experimental group achieved a mean score of 0.51, categorized as moderate. These findings indicate that the implementation of the Problem-Based Learning model is more effective in improving students' spatial thinking skills compared to traditional instructional methods.

4.2 Assumption Test Results

Prior to conducting hypothesis testing, prerequisite tests were performed, namely the normality and homogeneity tests. In the normality test, the significance values in the Kolmogorov–Smirnov column were above 0.05 for the control class pretest, the experimental class pretest, and the experimental class posttest. However, this was not the case for the control class posttest, as its significance value was below 0.05. Meanwhile, the results of the Shapiro–Wilk test indicated that all classes had significance values above 0.05. Therefore, it can be concluded that, overall, the pretest and posttest data from both the experimental and control classes were normally distributed. Furthermore, based on the homogeneity test results, the significance value in the “Based on Mean” column was greater than 0.05, indicating that the data were homogeneous. Consequently, the researcher decided to employ a parametric independent samples t-test for hypothesis testing.

Kelas	Kolmogorov-Smirnov ^a			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
Hasil	Pretest A (kontrol)	,142	36	,063	,967	36	,344
	Posttest A (kontrol)	,148	36	,045	,962	36	,240
	Pretest B (eksperimen)	,142	36	,063	,967	36	,344
	Posttest B (eksperimen)	,136	36	,091	,955	36	,148

a. Lilliefors Significance Correction

Figure 8. Results of the Normality Test Using SPSS

(Source: Research findings, 2025)

Nilai		Levene	df1	df2	Sig.
		Statistic			
	Based on Mean	,007	1	70	,933
	Based on Median	,003	1	70	,955
	Based on Median and with adjusted df	,003	1	69,854	,955
	Based on trimmed mean	,006	1	70	,938

Figure 9. Results of the Homogeneity Test Using SPSS

(Source: Research findings, 2025)

4.3 Hypothesis Testing Results

The results of the independent samples t-test revealed a significance value (Sig. 2-tailed) of 0.000, which is lower than the established significance level of 0.05. Therefore, it can be concluded that there is a statistically significant difference in learning outcomes between students in the experimental class and those in the control class. This finding indicates that the implementation of the Problem-Based Learning (PBL) model has a significant effect on improving students' spatial thinking skills. In other words, the observed difference is not due to chance, but rather a direct result of the application of the instructional model.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Nilai	Equal variances assumed	6,809	,011	-8,285	70	,000	-,293	,035	-,363	-,222
	Equal variances not assumed			-8,285	56,994	,000	-,293	,035	-,363	-,222

Figure 10. Results of the Independent Samples t-Test
(Source: Research findings, 2025)

Furthermore, the findings of this study indicate that the implementation of the Problem-Based Learning (PBL) model provides a more in-depth learning experience compared to the conventional method applied in the control group. Through PBL, students in the experimental group were encouraged to investigate problems, conduct analyses, and formulate solutions through critical and spatial thinking processes. This approach contributed to significantly higher posttest scores. Thus, PBL can be identified as an effective instructional approach for enhancing students' spatial thinking skills at the senior high school level.

4.4 Discussion

Regarding the first research question, namely the implementation of the Problem-Based Learning (PBL) model to enhance the spatial thinking skills of Grade XI students at SMA N 1 Pringsewu, this study was conducted at SMA Negeri 1 Pringsewu from June to July 2025 in the 2025/2026 academic year. Prior to the implementation of the study, the researcher conducted an instrument prerequisite test in Class XI F.2 to ensure the validity and feasibility of the test items. Subsequently, the experimental procedures were carried out to examine the implementation of the Problem-Based Learning model in improving students' spatial thinking skills in the experimental class. This study employed a Pretest-Posttest Control Group Design. The sample was divided into two classes: Class XI F.1 as the control group and Class XI F.10 as the experimental group. In this learning process, the researcher acted as the teacher.

The Problem-Based Learning model was implemented exclusively in the experimental class and was conducted over three meetings. PBL was selected as the instructional model because the intended learning objectives aligned with the stages of the Problem-Based Learning model (Nurcahyo & Winanti, 2021). According to Sumarmi (2012), the PBL model consists of five syntactic stages: (1) orienting students to the problem; (2) organizing students for learning; (3) guiding individual and group investigations; (4) developing and presenting the results; and (5) analyzing and evaluating the problem-solving process. The detailed explanation of the instructional process is as follows:

In the first stage, namely orienting students to the problem, the researcher delivered the material using PowerPoint presentations displayed at the front of the class and provided a video as an initial stimulus to provoke inquiry (Sahfitri, 2024; Afriandy et al., 2024). Based on the observation sheet, most students were able to understand the given topic, independently identify problems, and relate them to their surrounding environment (Sahfitri, 2024). This indicates that students began to engage in spatial thinking by attempting to understand the relationship between location and events.

The second stage involved organizing students for learning. At this stage, the researcher divided students into groups and distributed case study worksheets to each group, with instructions that each group discuss a specific type of disaster. Based on the observation results, this stage was implemented very effectively. Students appeared highly enthusiastic during discussions and actively explored the problems presented in the Student Worksheets (LKPD). This activity strengthened their spatial abilities, as they exchanged ideas regarding the spatial thinking indicators applied in the LKPD, which included comparison, aura, region, understanding orientation and direction, and understanding spatial forms and patterns within the context of the problem being studied (Wijaya et al., 2025; Ain et al., 2025).

Third stage: guiding individual and group investigations. At this stage, students begin discussions by seeking information and compiling it collaboratively based on each group's Student Worksheet (LKPD). In this phase, students are able to understand and interpret map data as well as geographic symbols to answer the questions in the LKPD, which is one indicator of their spatial thinking ability (Viona & Ahyuni, 2024). Observation results show that students are also capable of proposing various alternative solutions based on their interpretation of the spatial data they analyzed (Aliman, 2020).

Fourth stage: developing and presenting work results. At this stage, the researcher directs students to present the results of their Student Worksheets (LKPD) in front of the class. Students, in groups, present or explain the outcomes of the discussions they have conducted (Bayu Pramarta & Yuniarika Parwat, 2025). Based on observation sheets, students are able to express their opinions clearly using spatial terminology such as direction, location, and distribution. When presenting their work, they also demonstrate the ability to display visual data such as tables, which strengthens the solutions they propose to the problems discussed.

Fifth stage: analyzing and evaluating the problem-solving process. The researcher conducts activities in the form of reviewing the material or group learning outcomes that have been carried out by all students. From the observations, active students are able to assess the strengths and weaknesses of the solutions they developed by considering the spatial context of the problems discussed. They also show a good understanding of geographic concepts and spatial relationships when formulating final conclusions. This ability indicates development in higher-order thinking, particularly in critical spatial thinking (Junita & Wijayanto, 2024).

Regarding the second research problem, namely the effect of the Problem Based Learning model on the spatial thinking ability of Grade XI students at SMA N 1 Pringsewu: the Problem Based Learning (PBL) model, according to Johnson in Sumarmi (2012), has five main syntaxes: orienting students to problems, organizing students for learning, guiding individual and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process.

Each syntax emphasizes higher-order thinking activities, independent inquiry, collaboration, and problem solving based on real contexts. These characteristics make PBL relevant for developing students' cognitive abilities, including abilities related to spatial analysis.

Meanwhile, spatial thinking ability according to AAG (2008) and Bednarz & Lee (2019) includes indicators such as comparison, aura, region, understanding orientation and direction, and understanding spatial shapes and patterns. These indicators require students to be able to compare spatial data, recognize relationships among geographic phenomena, understand regional structures, and interpret geosphere distribution patterns. This process requires not only conceptual understanding but also applicative skills when linking geographic data to real conditions.

The relationship between the two theories becomes evident when PBL syntaxes are applied in geography learning. From the problem-orientation stage to investigation, students are confronted with spatial phenomena that require comparison, region, and aura abilities to analyze. Investigative activities make students interact directly with maps, diagrams, imagery, or other spatial data so that spatial thinking indicators are naturally trained. Furthermore, the stages of presenting results and evaluation facilitate the ability to understand orientation, direction, shapes, and spatial patterns through the preparation of analytical work and reflection on the solutions provided.

Thus, PBL and spatial thinking ability have a mutually reinforcing relationship. PBL provides a learning flow that encourages spatial exploration and reasoning, while spatial thinking indicators develop optimally through problem-solving activities that form the core of PBL. The combination of these two theories explains why PBL is an effective model for improving students' spatial thinking abilities.

This study shows that the implementation of the Problem Based Learning (PBL) model has a positive impact on students' spatial thinking abilities compared to conventional teaching methods. Students who participated in PBL learning in the experimental class showed better improvement in spatial thinking skills than the control group, as seen from the increasing number of students who achieved mastery criteria across various spatial ability indicators (Sasmita et al., 2015). This occurs because PBL requires students to be actively involved in analyzing real problems related to geographic contexts, thereby motivating them to apply spatial thinking skills in solving problems.

First, PBL increases student participation and engagement. Students in the experimental group demonstrated higher levels of activeness in discussions, map analysis, and presenting their work compared to the control group. This is in line with the study by Sihombing (2024), which showed an increase in student involvement in group discussions from 75% to 87%, as well as improved activeness and confidence in speaking in front of the class after the implementation of PBL. This confirms that PBL can directly enhance student participation in the learning process.

Second, PBL develops critical and creative thinking skills. Through problem-based LKPD, students become accustomed to analyzing regional differences, disaster impact patterns, and mitigation strategies. This process requires both critical and creative thinking skills. According to Sari et al. (2022), PBL-STEM-based e-LKPD proved effective in improving students' disaster literacy skills, with a high effect size (0.72) and an N-gain of 0.68. The product was also considered highly engaging, user-friendly, and beneficial for students.

Third, PBL enhances collaboration skills. In this study, discussion groups enabled students to share information to better understand spatial indicators. Ifada et al. (2024) found that the implementation of Problem Based Learning significantly improved students' collaboration skills, as indicated by increased individual contributions, better time management, more effective group problem solving, and stronger involvement in teamwork following the application of the PBL model in learning.

Fourth, PBL fosters learning independence. Students are encouraged to seek additional information sources from thematic maps, satellite imagery, and available spatial data, so they do not rely solely on the teacher. Karimah & Pratama (2025) found that the implementation of the Problem Based Learning model contributed significantly to the development of students' learning independence, with students demonstrating better ability to regulate their own learning processes, search for additional reference materials, and think and solve problems without heavy dependence on teacher explanations.

Fifth, PBL connects learning with real-world contexts. The implementation of PBL in this study focused on disaster-related problems connected to students' daily lives, making the learning experience more meaningful. This is consistent with research by Sari & Darmayanti (2024), which showed that applying PBL to disaster preparedness material effectively improved students' anticipatory competency regarding potential disasters, proving that learning rooted in real situations enhances students' understanding and preparedness.

In conclusion, the PBL approach not only improves learning outcomes quantitatively but also qualitatively helps students develop deeper spatial thinking. PBL has proven effective in strengthening students' skills in analysis, comparison, classification, understanding direction, and recognizing spatial patterns. Therefore, PBL can be considered a relevant and efficient alternative teaching method for improving the quality of geography education, particularly in the domain of spatial thinking skills.

5. CONCLUSION

Based on the research conducted, it can be concluded that the implementation of the Problem Based Learning (PBL) model at SMA N 1 Pringsewu was carried out effectively in accordance with the established learning syntax. This is evident from the increased student participation in discussions, map analysis, and the presentation of their work results. As a result, all spatial thinking indicators—comparison, aura, region, orientation and direction, as well as spatial shapes and patterns—were successfully achieved.

In addition, PBL had a positive impact on students' spatial thinking abilities, as reflected in the learning outcomes of the experimental class, which were better than those of the control class, along with an increase in the number of students who met the mastery criteria. Therefore, PBL has proven to be effective in improving students' spatial thinking skills, both through a more interactive learning process and through better learning outcomes compared to conventional teaching methods.

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