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Problem-Based Learning in Geography Education: The Effect on Spatial Thinking and Flood Preparedness Attitudes in Senior High School Student

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ABSTRACT

Floods are a dominant hydrometeorological disaster in Indonesia, requiring early preparedness from the students. However, observations show a gap between the high risk of flooding in the students' environment and their low spatial thinking skills and preparedness attitudes due to the dominance of conventional learning. This study aims to examine the effect of the Problem-Based Learning (PBL) model based on contextual problems on students' spatial thinking skills and preparedness attitudes towards flood disasters. This study used a quasi-experimental nonequivalent control group design, with two classes as research subjects, namely the experimental class and the control class. The data collection instruments used were a validated spatial thinking ability test and preparedness attitude questionnaire. Data analysis used the Independent Sample T-Test and Mann- Whitney U tests. The results showed that the PBL model had a significant effect on spatial thinking ability ($p < 0.001$), with a large effect category ($d = 1.045$). In addition, PBL also had a significant effect on disaster preparedness attitudes ($0 = 0.026$), with a medium effect size ($r = 0.306$), as indicated by a change in category from "ready" to "very ready." This study proves that the integration of contextual flood problems in PBL syntax effectively stimulates students' spatial visualization and facilitates the internalization of risks that shape disaster response character. This study contributes to the development of geography learning strategies on disaster preparedness attitudes and emphasizes their application for a young generation that is resilient in facing hydrometeorological disasters.

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1. Introduction

The World Risk Report 2024 ranks Indonesia second out of 193 countries with the highest disaster risk in the world. This is confirmed by data from the National Disaster Management Agency (BNPB), which recorded 3,472 disaster events in 2024. A total of 99.34% were hydrometeorological disasters influenced by weather and climate factors. Floods dominated the statistics with 1,420 incidents, surpassing extreme weather (733 incidents) and landslides (207 incidents). The high frequency of floods demands urgent mitigation, namely preparedness to reduce disaster risk (Li et al., 2023; Tay et al., 2022). Analysis of the results of disaster risk assessments for each province in Indonesia from 2010-2020 shows that the most common phenomenon is hydrometeorological, namely flooding (Azizah et al., 2021; Putri et al., 2021).

Data from the Malang City Disaster Management Agency (BPBD) shows an increase in flooding in residential areas around the Amprong rivers over the past three years. This situation affects students at State Senior High School 6 Malang, who are geographically located in the Buring buffer zone but many of whom live in areas prone to flooding (Paper & Nguyen, 2023). Initial observations at the school revealed a gap in spatial literacy, as students only memorized the definition of disasters without being able to analyze spatial phenomena in their surroundings. As many as 60% of students failed to identify safe zones and evacuation routes based on the flood potential map provided. This research by Handoyo et al. (2024), which shows that the spatial thinking abilities of high school students in Indonesia are still in the low to moderate category, especially in terms of visualization and map interpretation. This condition indicates that conventional learning methods have not been effective in developing spatial reasoning, which is important for disaster preparedness (Duarte et al., 2022; Khan et al., 2023). The more effective students are in analyzing risk maps and evacuation routes, the more effective emergency response planning will be in minimizing the impact (Song et al., 2022).

Schools play an important role in disaster management efforts because they can improve students' knowledge, preparedness, and skills, both on a personal and household scale. Disaster-related material in geography lessons can help students understand the nature of disasters and efforts to reduce the risks they pose (Cvetković et al., 2024). In addition, students play a role as agents of change, who are expected to be able to deal with emergency situations and actively participate in minimizing damage to the surrounding environment (Ridha et al., 2022). However, the effectiveness of learning is highly dependent on students' understanding of the characteristics of disasters, thus requiring specific cognitive competencies (Westman et al., 2024). One cognitive aspect in disaster management is spatial thinking ability. This ability allows students to understand the location, distribution, patterns, and relationships between phenomena on the earth's surface (Duarte et al., 2022; McLaughlin & Bailey, 2023). The ability to visualize spatial hazards plays an important role in connecting cognitive understanding to affective responses (Gagnier et al., 2022). Students with good spatial literacy can project the real impact of disasters in their minds, and psychologically stimulate greater awareness and a more responsive attitude of preparedness (Cvetković et al., 2024). The better students' spatial thinking skills, the more accurate their ability to analyze risk maps, understand evacuation routes, and plan emergency responses (Duarte et al., 2022; Song et al., 2022). However, spatial thinking skills cannot be taught directly, but rather integrated into learning models, one of which is Problem-Based Learning (PBL).

The PBL learning model is considered effective in facilitating the development of higher-order thinking skills and real-world problem solving. PBL has the following stages of problem-based learning: a) orienting students to the problem, b) organizing students to learn, c) guiding individual and group investigations, d) developing and presenting work results, e) analyzing and evaluating the problem-solving process (Sukackė et al., 2022). PBL learning model has several advantages in terms of student engagement; Retention of material. Problem-solving strategies have been proven effective in deepening understanding of lesson content, Intellectual satisfaction. The inquiry process provides challenges as well as intrinsic satisfaction for students, Increased activity. It increases dynamics and active participation in class, Knowledge transfer. It helps students apply academic understanding to everyday problems, Mindset transformation (Wilmot et al., 2025). It shifts the learning paradigm from receiving textual information to a process of critical and responsible thinking (Granados-Sánchez, 2022). The relevance of this model is even stronger in disaster education, as flooding is a complex (ill-structured problem) that requires multidimensional solutions and analysis. The characteristics of flood problems require students to investigate spatial data. Previous research has shown that the PBL model helps students solve problems triggered by material on village and city interactions, namely the problem of road damage, which connects villages and the city outskirts (Retscher et al., 2022). The application of the PBL model is important because it helps students learn more actively, build problem-solving skills, develop critical thinking, and build collaboration with teams to face problems (Golightly & Raath, 2015; Sonrum & Worapun, 2023).

Previous studies by Handoyo et al. (2024) have proven the effectiveness of the PBL model in improving spatial thinking skills, but only in terms of cognitive aspects learning outcomes. Other studies on disaster preparedness attitudes by (Guo et al., 2025) and (Sun et al., 2024) focused more on students' knowledge levels without integrating specific learning model interventions. The results of the literature study show a lack of exploration of the PBL model in stimulating spatial thinking skills and shaping attitudes toward flood disaster preparedness, especially at the high school level. This study was conducted to fill the gap through an integrative approach, which connects learning syntax with the improvement of spatial competence and disaster mitigation attitudes in students.

Based on the urgency of mitigation issues and theoretical gaps that have been described, this study aims to examine the effect of applying the PBL model on spatial thinking skills and flood disaster preparedness attitudes at State Senior High School 6 Malang. Unlike conventional approaches, this study examines how contextual problem intervention in PBL can stimulate students' spatial thinking skills, which contribute to the formation of preparedness attitudes, making them more responsive. The results of this study provide empirical contributions to the application of the PBL model in Geography learning that is adaptive to disaster risk reduction.

2. Method

2.1. Research Design

This study used a quantitative approach with a quasi-experimental design, namely a nonequivalent control group design. This design was chosen because the researchers could not fully control external variables and could not randomly assign research subjects, as the classes had already been formed. This research design involved two groups, namely the experimental group that received the Problem-Based Learning (PBL) model treatment and the control group with the conventional model.

Tabel 1. Non-Equivalent Control Group Research Design

Group	Pre-test	Perlakuan	Post-test
Experimental	O1	X1	O2
Control	O1	X2	O2

Description:
Experiment: Group using the PBL model.
Control: Group using the conventional learning model.
O1: Pretest of spatial thinking ability and preparedness attitude
O2: Posttest of spatial thinking ability and preparedness attitude
X1: Treatment using the PBL model.
X2: Treatment using the conventional model.

2.2. Time and Location

The research was conducted in the even semester of the 2024/2025 academic year at State Senior High School 6 Malang (Jalan Mayjen Sungkono No. 58, Buring, Kecamatan Kedungkandang, Kota Malang, Jawa Timur). The location was chosen based on the potential for disaster vulnerability in the Malang area and the need to strengthen disaster mitigation among students at the school. The research location map is presented in Figure 1.

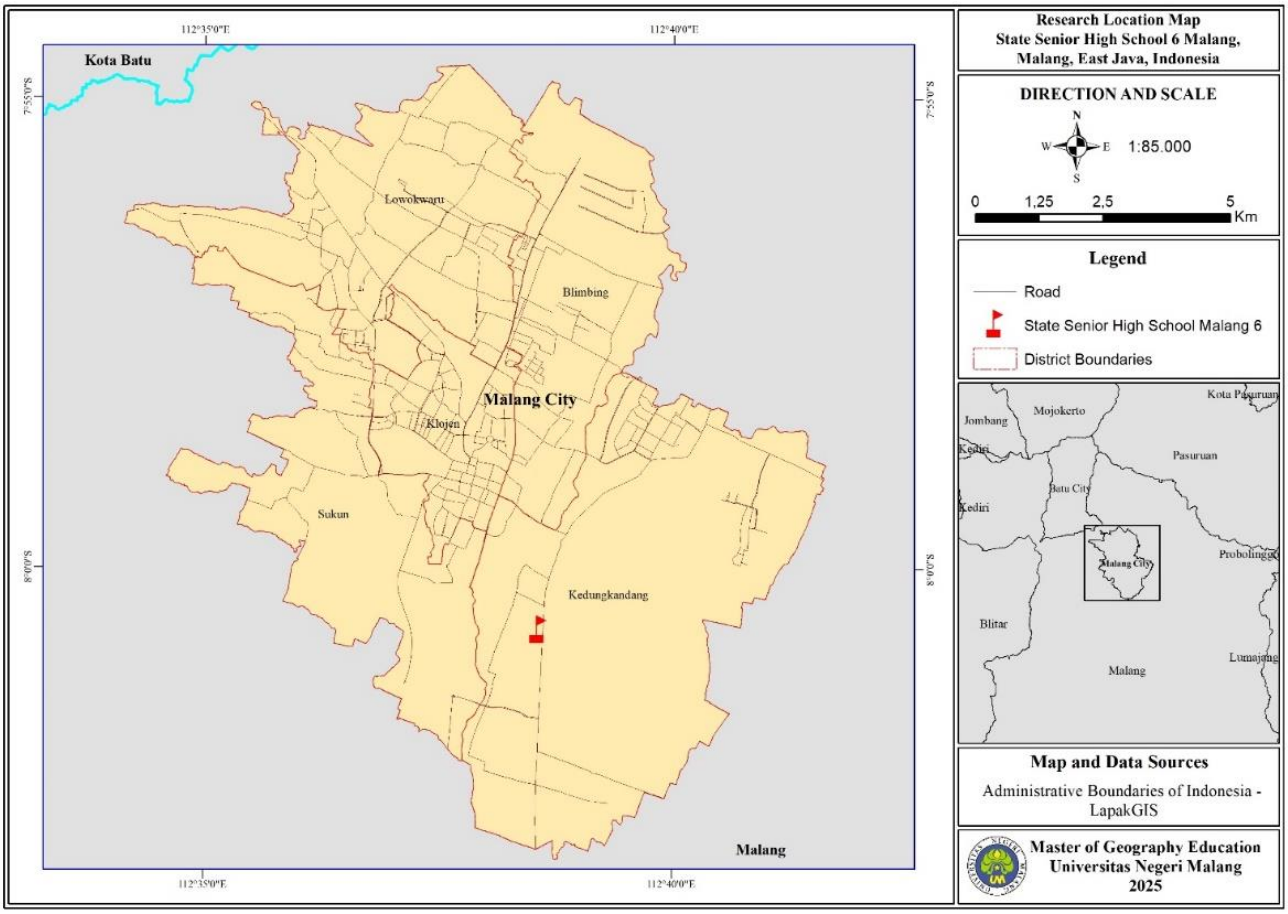

Figure 1. Research location map

2.3. Research Subject

The subjects of this study were tenth-grade students at State Senior High School 6 Malang in the second semester of the 2024/2025 academic year. This study used purposive sampling selected based on several criteria, namely classes taught by the same teacher to avoid teacher bias, and both classes had equivalent initial academic abilities. This equivalence in initial abilities was based on an analysis of the homogeneity of test scores on previous Geography material, which showed no significant difference between the variances of the two classes. The research subjects are presented in Table 2.

Table 2. Research subjects

Class	Group	Male	Percentage	Female	Percentage	Total
X.9	Experiment	14	38.89%	22	61.11	36
X.10	Control	13	37.14%	22	62.86%	35

2.4. Experimental Procedure

The research procedure was carried out in three stages, namely the preparation stage, implementation stage, and evaluation stage during four meetings (2 × 45 minutes) face-to-face. The preparation stage was carried out by giving a pretest to measure students' initial spatial thinking abilities. The implementation stage was the stage of applying the PBL model in the experimental class, which was integrated with material on atmospheric dynamics and disaster mitigation. The learning activities followed the PBL syntax, which is described Figure 2.

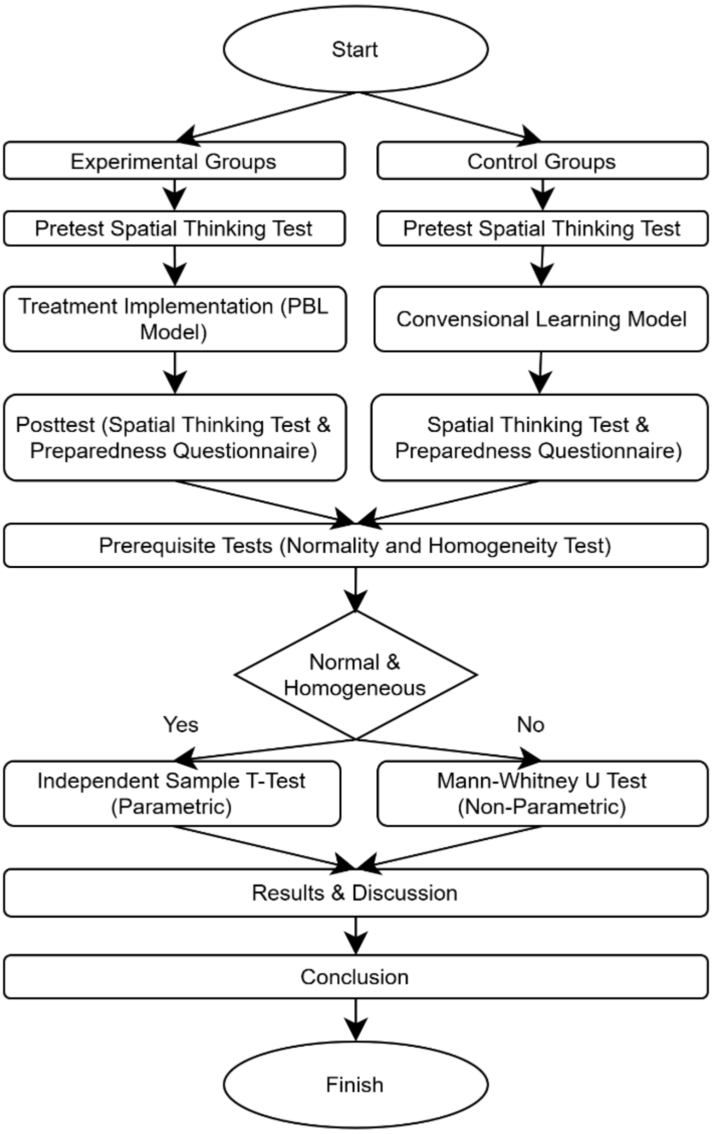

Figure 2. Experimental procedure

The learning activities followed the PBL syntax, which is described as follows: 1) Orienting students to the problem. The researcher began the lesson by explaining the learning objectives and presenting a contextual problem in the form of flooding in Malang to motivate students to actively engage in problem-solving activities. 2) Organizing students to learn. Students defined and organized tasks related to the flooding problem and formed discussion groups on the roles and strategies for solving the problem. 3) Guiding individual and group investigations. Students gathered information and conducted investigations to obtain explanations and solve problems. 4) Developing and presenting work. Students plan and prepare appropriate work, such as analysis reports, mitigation videos, or risk maps, and share tasks and roles so that the presentation of results runs effectively. 5) Analyzing and evaluating the problem-solving process. Researchers reflect on and evaluate the results of student investigations and the learning process that has been undergone.

In the control class, learning was carried out using a conventional model conducted by the teacher, namely the lecture method. The researcher delivered the material directly (lecture) and gave exercise assignments. The activity ended with an evaluation stage, namely giving a post-test to both groups to measure the improvement in students' spatial thinking skills and their attitude of preparedness for disasters. The research procedure flow is shown in Figure 2.

2.5. Research Instrument

The data instruments used in this study were a spatial thinking ability test and a disaster preparedness attitude questionnaire. The spatial thinking ability test questions were adopted and developed from the instrument by (Aliman, 2020), which consisted of six indicators, namely comprehensiveness, spatial interaction, scale, analysis, representation, and application. The disaster preparedness questionnaire was adapted from (Lukman & Masinu, 2020) instrument, which consists of 11 statements with two indicators, namely plans to respond to emergencies (6 statements) and assistance and rescue (5 statements). Preparedness was measured using a 4-level Likert scale, ranging from very prepared (VP) to not yet prepared (NP). Validity and reliability tests were conducted before the instruments were used. The validity test results showed that the items were valid with a rhitung range of 0.641 to 0.680. The reliability test using Cronbach's Alpha formula with SPSS showed a coefficient value of 0.709, which means that the instrument is reliable and suitable for use.

2.6. Data Analysis

Data analysis was performed using descriptive and inferential statistical techniques. Descriptive statistics were used to present the mean, standard deviation, gain score, and student readiness index. Inferential analysis was used to test the research hypothesis, using a difference test (t-test) at a significance level of 5% (α=0.05). Prior to testing the hypotheses, a prerequisite analysis test was conducted, consisting of a normality test (Shapiro-Wilk, because the data was below 50) and a homogeneity test (Levene's Test) to determine the normality and homogeneity of the data. Signifikansi statistik ditentukan dengan mengevaluasi apakah nilai p dari uji t mencapai tingkat α yang telah ditentukan sebesar 0,05, dengan $p \geq \alpha$ mengakibatkan retensi hipotesis nol (Ho) dan penolakan hipotesis alternatif (Ha). Data that met the prerequisite tests were analyzed using parametric statistical tests (Independent Sample T-Test), and non-parametric statistical tests (Mann-Whitney U) were used if the data did not meet the prerequisite test. The results of the descriptive percentage analysis, then the scores obtained are consulted with the criteria Table 3.

Tabel 3. Student Readiness Level Categories

Percentage	Criteria
81,25 – 100	Very Ready
62,50-81,24	Ready
43,75-62,49	Not Quite Ready
25-43,74	Not Ready

3. Results

3.1. Research Data Description

The research data obtained from the pretest and posttest scores in the experimental class and control class are shown in Table 4.

Table 4. Data on Spatial Thinking Ability and Spatial Thinking Readiness Attitude

	Grup	N	Mean	SD	SE	Coefficient of variation	Mean Rank	Sum Rank
Spatial Thinking Ability	Pretest Experimental	36	25.83	4.63	0.77	0.17	39.94	1438.00
	Posttest Experimental	36	35.03	3.90	0.65	0.11	45.61	1642.00
	Pretest Control	35	24.40	3.99	0.65	0.16	31.94	1118.00
	Posttest Control	35	30.57	4.61	0.78	0.15	26.11	914.00
Attitude Readiness	Pretest Experimental	36	31.03	3.48	0.58	0.11	43.10	1551.50
	Posttest Experimental	36	36.39	3.92	0.65	0.11	41.36	1489.00
	Pretest Control	35	28.29	4.22	0.71	0.15	28.70	1004.50
	Posttest Control	35	34.37	3.64	0.62	0.11	30.49	1067.00

Table shows that the initial abilities of both groups were relatively the same. However, the experimental class showed a more significant increase in scores compared to the control class after receiving treatment. The post-test average of the experimental class on the spatial thinking ability variable reached 35.03 (an increase of 9.20 or 35.62%), while the control class only reached an average of 30.57 (an increase of 6.17 or 25.29%). In addition, the experimental class obtained an average of 36.39 on the preparedness attitude variable compared to the control class, which was only 34.37. On the disaster preparedness attitude variable, the experimental class experienced a higher increase than the control class. The results of the preparedness attitude index are shown in Table 5.

Table 5. Results of flood disaster preparedness attitude measurement

Class	Index			
	Pretest	Category	Posttest	Category
Experiment	70.52	Ready	82.70	Very ready
Control	64.29	Ready	78.12	Ready

Table 5 shows that the results of the flood disaster preparedness attitude index in the experimental class increased from the ready category to the very ready category, with the average score increasing from 70.52 to 82.70. As an experimental class, this class received problem-based learning. Meanwhile, the control class remained in the ready category with an average score of 64.29 to 78.12. For a clearer picture of these preparedness attitudes, the following data is presented in the form of scores per indicator for the experimental class and the control class

3.2. Prerequisite Test Analysis

3.2.1. Normality Test

The normality test used the Shapiro-Wilk technique for samples of less than 50 students per class, with a significance level of 5% (α = 0.05). The test criteria stated that the data was normally distributed if the significance value (p value) was greater than 0.05. The results of the normality test are shown in Table 6**.**

Table 6. Results of the normality test for spatial thinking ability

		W	p	Description
Spatial Thinking Ability	Experiment	0.959	0.199	Normal
	Control	0.976	0.612	Normal
Attitude Preparedness	Experiment	0.972	0.470	Normal
	Control	0.920	0.014	Not normal

Note. Significant results suggest a deviation from normality.

Table 6 shows the normality of different data on both measured variables. The significance value (p value) on the spatial thinking ability variable is greater than 0.05, which means that the data is normally distributed. However, the significance value of the preparedness attitude variable in the control class is 0.014 ($p < 0.05$), which means that the data is not normally distributed. These findings indicate the need to use non-parametric statistical tests such as the Mann-Whitney U test or Kruskal-Wallis test for analyzing preparedness attitude data so that the analysis results remain valid and reliable.

3.2.2. Homogeneity Test

The homogeneity test used Leven's test, as shown in Table 7.

Table 7. Results of Levene's Homogeneity Test

	F	df_1	df_2	p	Description
Spatial Thinking Ability	0.387	1	69	0.536	Homogeneity
Attitude Preparedness	0.323	1	69	0.572	Homogeneity

Table 7 shows the significance value (p value) for the spatial thinking ability variable of 0.536 and the preparedness attitude variable of 0.572, which are greater than 0.05 ($p > 0.05$), so the data is homogeneous. Although both data sets are homogeneous, the determination of the hypothesis test refers to the results of the previous normality test. The spatial thinking ability data meets the requirements of normality and homogeneity, so the analysis uses the Independent Sample t-Test parametric test. The preparedness attitude data is homogeneous but not normally distributed, so the analysis uses the Mann-Whitney U Test non-parametric test.

3.3. Hypothesis Test Results

3.3.1. The Effect of the Problem-Based Learning Model on Spatial Thinking Ability

The first hypothesis test aims to prove the effect of the Problem-Based Learning (PBL) model on students' spatial thinking ability. The analysis was conducted in two stages, namely (1) determining the improvement of each class using the Paired Sample t-Test, and (2) testing the effectiveness using the Independent Sample t-Test. The results of the Paired Sample t-Test (Table 6) show that the experimental class and the control class experienced a significant increase in spatial thinking skills, as indicated by a significance value (p-value) of <0.001 ($p < 0.05$). However, to prove that the increase in the PBL class was more significant than in the control class, an Independent Sample t-Test was conducted, as shown in Table 8**.**

Table 8. Dependent (Paired) Sample t-Test Spatial Thinking

Pretest		**Posttest**	**t**	**df**	**p**	**Cohen's d**	**SE Cohen's d**
Spatial Thinking Ability Exsperimental	-	Spatial Thinking Ability Exsperiment	-10.262	34	< .001	-1.735	0.344
Spatial Thinking Ability Control	-	Spatial Thinking Ability Control	-8.599	34	< .001	-1.453	0.237

Note. Student's T-test.

Table 9. Independent Sample t-Test Spatial Thinking Ability

	Test	**Statistic**	**df**	**p**	**Effect Size**	**SE Effect Size**
Spatial Thinking Ability	Student	4.401	69	< .001	1.045	0.267

Note. For the Student t-test, effect size is given by Cohen's d. For the Mann-Whitney test, effect size is given by the rank biserial correlation.

Table 9 shows a significance value (p-value) of < 0.001 ($p < 0.05$). These results prove that there is a significant difference in the average spatial thinking ability between the experimental class using PBL and the control class using the conventional model. This result is reinforced by a positive mean difference of 4.456. This result is also supported by an Effect Size (Cohen's d) of 1.045, which is categorized as a large effect. These findings prove that the PBL learning syntax has a positive and effective impact on developing students' spatial thinking skills compared to the conventional lecture method.

3.3.2. The Effect of the Problem Bassed Learning Model o Disaster Preparedness Attitudes

The second hypothesis test aims to determine the effectiveness of the PBL model on students' disaster preparedness attitudes. Based on the prerequisite test, the analysis was conducted using the Mann-Whitney U Test nonparametric test, as shown in Table 10**.**

Table 10. Mann-Whitney U Test For Disaster Preparedness Attitudes

	Test	**Statistic**	**df**	**p**	**Effect Size**	**SE Effect Size**
Attitude of Preparedness	Mann-Whitney	823.000		0.026	0.306	0.137

Note. For the Student t-test, effect size is given by Cohen's d. For the Mann-Whitney test, effect size is given by the rank biserial correlation.

Table 10 shows a significance value (p-value) of 0.026, which is less than 0.05. This result proves that the PBL model has a significant effect on students' preparedness attitudes. In addition, the Effect Size (Rank Biserial Correlation) value of 0.306 shows that the PBL model has a "moderate" impact on improving students' preparedness attitudes. These results conclude that student involvement in solving flood problems can foster greater awareness and a more anticipatory attitude.

4. Discussion

4.1. The Effect of Problem Based Learning on Spatial Thinking Ability

The hypothesis test results show that the application of the PBL model has a significant effect on students' The hypothesis test results show that the application of the PBL model has a significant effect on students' spatial thinking skills ($p < 0.001$). This result is reinforced by an effect size value of 1.045, which is classified as a large effect. This indicates that the PBL model is more effective in stimulating students' spatial intelligence than the conventional lecture-based model. These findings are in line with the research by Handoyo et al. (2024), who applied the PBL model to improve high school students' spatial thinking abilities. They found that the PBL model was able to stimulate students to analyze spatial phenomena in depth through contextual problem orientation syntax and group investigation.

The improvement in spatial thinking skills in the experimental class occurred due to the syntactic characteristics of PBL, which placed spatial problems as the starting point for learning. Students were shown the phenomenon of flooding that occurred in their surrounding environment, namely the Amprong River Basin and Kampung Warna-Warni, at the problem orientation stage. This exposure to the problem stimulated comprehensive indicators and spatial interaction, as students were required to identify the location of the event and analyze the spatial relationships between the causes of flooding. The control class only received a verbal definition of flooding, while the experimental class began their learning by visualizing "where" and "why" flooding occurred at that location. Students not only memorize definitions of disasters, but also build mental representations of risk distribution, flood spread patterns, and spatial relationships between geographical elements in their environment. This is in line with (Silviariza et al., 2020) research on Spatial Problem-Based Learning (SPBL), which emphasizes the importance of integrating a spatial approach into problem-based learning to optimize geographical critical thinking skills.

The students' cognitive processes were further honed during the group investigation stage. Activities exploring digital maps, rainfall data, and topography required students to conduct comprehensive and in-depth spatial analysis. Research by (Kerski, 2023) shows that integrating real-world problems with geospatial data can train students to translate map symbols into mitigation information. Students learn to connect river flow patterns with population density, which is a high level of spatial thinking (Fadjarajani et al., 2024).

The advantage of the PBL model also lies in the principle of constructivism. PBL facilitates spatial thinking analysis skills. Students are not only asked to describe geographical phenomena, but also to analyze distribution patterns, spatial interactions, and predict the impact of disasters based on regional characteristics. (Silviariza & Handoyo, 2020) research in his study on hybrid problem-based learning shows that a problem-based learning model integrated with a spatial approach can improve not only spatial thinking skills but also overall geography learning outcomes.The process of solving flood problems requires students to construct spatial knowledge through observation and inference. This is in line with McLaughlin & Bailey (2023) findings, which state that student involvement in solving spatial problems can significantly improve spatial reasoning skills. Conversely, the low achievement in the control class was due to minimal stimuli and a lack of challenges in problem solving, so that students' spatial thinking skills in visualizing spatial phenomena were underdeveloped (Duarte et al., 2022). Supporting this view, (Hawes et al., 2022) demonstrated through a large-scale meta-analysis of 217 studies that spatial skills are highly malleable and can be substantially improved through targeted training, underscoring the importance of deliberate pedagogical design. In the geography education context, systematically reviewed studies across K–12 settings and found that inquiry-based and problem-oriented approaches were significantly more effective than direct instruction in developing students' spatial reasoning capabilities (Howell & Maddox, 2024; Mašterová, 2023)

Research by Fadjarajani et al. (2024) states that problem-based learning with geospatial technology can improve cognitive processes in students' spatial thinking, including visualization, analysis, and spatial problem-solving skills. These findings are relevant to the context of this study, in which the experimental class showed significant improvement in their ability to analyze flood risk maps, identify safe zones and evacuation routes, and address problems in their environment**.**

4.2. The Effect of Problem Based Learning on Disaster Preparedness Attitudes

Statistical analysis results prove that the PBL model has a significant effect on students' disaster preparedness attitudes ($p = 0.026$), which is reinforced by an effect size of 0.306, categorized as medium (medium effect). The indicator of success can be seen from the transformation of the experiment class's preparedness category from "ready" to "very ready," while the control class remained in the "ready" category. This change in attitude occurs through a process of risk internalization facilitated by PBL syntax. PBL requires students to face threats through planning simulations, thereby actively involving them in the learning process. Students are invited to analyze the vulnerability of their residential areas, which are located near the Amprong river basin.

The application through PBL forms a mechanism of preparedness. When students are actively involved in analyzing real flood disaster problems in their surroundings, a psychological process occurs whereby students project the real impact of disasters in their minds. This process of risk visualization triggers greater awareness and a more responsive attitude of preparedness. Research conducted by Cho & Kwon (2025) found that learning that integrates disaster risk visualization not only improves critical thinking skills but also students' self-efficacy in dealing with emergency situations. This high self-efficacy is an important component of preparedness, as it reflects students' belief that they are capable of taking effective protective measures when faced with disaster threats.

This engagement connects cognitive knowledge about floods with affective responses to act. Students do not view floods as lesson material, but as a real risk that requires preparedness. A significant improvement in the emergency response plan indicator shows that students are able to understand spatial abilities, which become concrete mitigation actions. In the process of preparing their work (fourth syntax), students designed evacuation routes and meeting points based on risk maps that were analyzed collaboratively. This activity trains students' planning and responding simultaneously. This is in line with research Choi et al. (2025), which found that well-developed spatial literacy correlates positively with mitigation behavior, as when students are able to visualize hazards spatially, mental and technical preparedness will automatically develop. Research Intaramuean et al. (2025) research found that flood education programs that integrate local topographical information significantly improve students' preparedness for floods, even though there were no significant differences in flood risk perception between groups. This shows that increased preparedness can occur through improved knowledge and practical skills, even when risk perceptions are relatively stable.

Conversely, the stagnant category in the control class shows the weakness of conventional methods in imparting and fostering disaster awareness. Verbal knowledge transfer only provides short-term retention and lacks emotional involvement, resulting in a lack of preparedness. These findings are consistent with the research by Castaño et al. (2025), which states that problem-based active learning is a core element in transforming disaster knowledge into a responsive preparedness attitude, which contributes to the resilience of the school community and the students' surrounding environment.

4.3. Implications and Limitations of the Study

The results of this study recommend a paradigm shift in teaching geography related to disasters, from expository methods to problem-based learning. Teachers are advised to utilize local disaster phenomena, such as flooding in the school environment, as objects of study. A contextual approach can connect spatial thinking with the formation of disaster preparedness character. These findings reinforce the argument that schools play an important role in disaster preparedness efforts by increasing students' knowledge, preparedness, and skills (Hoffmann & Muttarak, 2017) Geography education with a PBL approach can play an effective role in building a disaster-responsive community. Research conducted by (Calamba, 2024) on the level of awareness and preparedness of high school students towards natural disasters in the Philippines found that there is a significant relationship between the level of awareness and the level of preparedness of students. Students who are highly aware of natural disasters tend to have better preparedness.

Students with good spatial thinking skills and preparedness attitudes can act as agents of change in their families and communities, as emphasized by (Fadjarajani et al., 2024; McLaughlin & Bailey, 2023). This study has a number of limitations. The research subjects were limited to one grade level at State Senior High School 6 Malang, so the results cannot be generalized to school populations with different geographical characteristics. The focus of the material was limited to floods, whereas Indonesia has a variety of hazards (multi-hazards), so future research is expected to expand the scope of disaster types, such as earthquakes or landslides, or integrate the PBL model with relevant geospatial technologies, such as augmented reality

5. Conclusion

Based on the results and discussion, this study produced two conclusions. First, the PBL model has a significant effect and a large impact on spatial thinking skills. The contextual problem orientation and group investigation stages proved to be effective in stimulating students to visualize and analyze spatial phenomena in depth compared to conventional models. Second, the PBL model has a significant effect on the formation of flood preparedness attitudes . Problem-based learning is able to facilitate the internalization of risk, which changes the category of student preparedness from "ready" to "very ready". This indicates that the active involvement of students in planning local disaster mitigation is more effective in building disaster response character than just transferring theoretical knowledge.

This study focused on one type of disaster (flooding) in a specific geographical context. To improve the generalization of the findings, further research needs to be conducted involving various types of disasters (earthquakes, landslides, tsunamis, etc.) and different geographical contexts.

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AI Use Declaration. The authors used Gemini Pro for language editing. The authors reviewed and edited all AI-assisted output and are fully responsible for its content and any errors.

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