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The influence of the map-assisted problem-based learning model and cognitive style on the spatial and critical thinking abilities of junior high school students

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Abstract: This study investigates the influence of the map-assisted Problem-Based Learning (PBL) model and cognitive styles on the spatial and critical thinking abilities of junior high school students. A quasi-experimental design with a 2×2 factorial structure was employed, involving 122 eighth-grade students. Participants were divided into two groups based on the learning model (map-assisted PBL and conventional PBL) and two cognitive style categories (Field Independent and Field Dependent). Data collection involved pre- and post-tests assessing spatial and critical thinking skills. The results of Multivariate Analysis of Variance (MANOVA) indicated that the map-assisted PBL model significantly enhanced both spatial and critical thinking abilities. Cognitive style also had a notable impact on spatial skills, with Field Independent students outperforming their Field Dependent counterparts. Additionally, a significant interaction between the learning model and cognitive style was observed concerning spatial abilities, although no significant effect was found for critical thinking. These findings underscore the importance of integrating cognitive characteristics into instructional design and highlight the effectiveness of map-assisted PBL in fostering spatial and critical thinking skills within social studies education. Practical implications suggest that educators should tailor learning strategies to students' cognitive styles to improve learning outcomes.

Keywords: *Cognitive style, Critical thinking, Interdisciplinary approach, Maps, Problem-based learning, Social studies. Spatial ability.*

1. Introduction

The subject of Social Sciences contains complex content that includes geography, history, economics, and sociology [1]. In learning practice, we often encounter problems of low student involvement and their limited ability to understand spatial concepts and think critically [2]. One of the main causes is the teaching approach, which still predominantly uses lectures (Direct Instruction) and does not take into account the cognitive characteristics of students [3, 4].

The Problem-Based Learning (PBL) model is a potential solution because it emphasizes active learning based on solving real problems [5]. This study integrates PBL with map media and an interdisciplinary approach to examine the relationship between these variables and two key skills: spatial ability and critical Thinking. In Integrated Social Studies (IPS) learning, PBL offers a dynamic and engaging approach to fostering a deeper understanding of complex concepts and fostering critical thinking skills. According to Kasmita and Khalsum [5] and Bell [6] unlike traditional classroom methods, PBL immerses students in real-world scenarios, encouraging them to investigate, analyze, and synthesize information from multiple sources. For example, solving a problem regarding the economic impact of globalization might require students to explore trade policies, cultural dynamics, and

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historical developments. According to Bell [6] and Dai, et al. [7] by actively participating in this problem-solving, students not only gain knowledge but also develop practical skills such as research, teamwork, and effective communication.

PBL in integrated social studies learning goes beyond memorizing facts [8]; it encourages students to apply theoretical frameworks to authentic problems [9] fostering a deeper appreciation for the interconnectedness of social phenomena [10]. Problem-based learning in social studies promotes a learner-centered approach, empowering students to take ownership of their education [11]. Students become active contributors to their learning experiences, developing a sense of autonomy and responsibility [12]. This approach also allows for personalized exploration of topics within the broader social studies curriculum, catering to diverse interests and learning styles [13]. Through collaborative problem-solving, students often engage in discussions, debates, and presentations, refining their ability to articulate ideas and perspectives—a crucial skill in navigating the complexities of the social world [14].

In addition to the use of appropriate learning models, namely student-centered through PBL, important problems often faced by educators in social studies learning activities are selecting or determining learning materials or teaching materials, and determining/selecting appropriate learning models in order to help students achieve competencies [15]. Regarding the selection of the use of maps in learning, in general, the problems in question include how to determine the type of map, depth, scope, order of presentation, and treatment of learning materials [16]. Maps are a very essential media for social science learning [17]. Maps are one type of learning media made in the form of horizontal images to actualize a number of abstract concepts related to learning materials that depict natural and social phenomena related to human life as social studies study material [18]. In addition to maps acting as a learning media, maps can also be used as learning resources, because all the concepts outlined in the map are essentially learning messages that can be used as study material for students in carrying out learning [19].

The use of maps as a learning instrument has been widely implemented in school subjects at various levels [20]. Maps are used in social studies at the junior high school level in Indonesia [21]. Given the educational level at which this subject is taught to adolescents, the topics covered include geography, economics, social studies, culture, history, politics, and so on, presented in a comprehensive and descriptive manner. The goal is for students to understand the spatial distribution of these topics. In other words, maps in social studies are used to visualize the interrelationships between the dynamics of human interaction with their environment in a broad sense.

The Integrated Social Sciences Approach is an integration of social sciences such as geography, economics, culture, history, politics, and so on, where geography is the platform of study [22]. Why is geography a platform for social science education? Because geography is a science that studies geosphere phenomena (phenomena of appearances on the Earth's surface) from a regional perspective [23]. This means that all natural and physical phenomena must occur in space on the Earth's surface, which is the main study material of geography. Social sciences based on geography require appropriate media to be able to explain these phenomena on the Earth's surface. The most appropriate media to represent the distribution of phenomena on the Earth's surface is a map. Thus, it can be concluded that whatever material is learned in social science learning, the main media must use a map..

Like other subjects in the science group, geography is a scientific study taught in junior high school, and it is one of the lessons summarized in integrated social studies, along with other subjects such as history and economics [24]. Until now, maps have not been widely used in social studies learning [25]. In fact, all social studies material can be visualized through maps, because all social phenomena, whether geographical, economic, historical, or sociological, occur on the Earth's surface. The Earth's surface is a spatial study that can be visualized in the form of a distribution on a map. Maps can be produced by students in PBL model activities when they analyze social phenomena on the Earth's surface. The application of map-based PBL is considered quite effective in conveying the content of social studies subjects, especially those related to spatial concepts. Map-based PBL is used as a learning model for students to more clearly understand the social studies subject as a whole.

Besides the learning model, many other factors influence learning outcomes. Okojie, et al. [25] stated that student learning outcomes are influenced by the learning model and student characteristics. Hal yang hampir sama disampaikan Slavin [26] echoed this sentiment, stating that student learning outcomes are influenced by: (1) the learning method or model applied, (2) the learning conditions, and (3) the interaction between the method and learning conditions. Reigeluth and Alison [27] argues that student characteristics, the quality, and the learning process are relevant to a person's learning outcomes.

Therefore, implementing an effective learning model requires consideration of student characteristics and conditions. One student characteristic that influences the implementation of learning strategies is their cognitive style. Santrock [28] emphasized that adapting a learning model to a student's cognitive style can improve achievement and behavior. According to Jacobsen, et al. [29] and Silberman [30] educators have recognized that students have different ways of acquiring knowledge. Some learn best only when others do the same [31].

Cognitive style needs to be considered as one of the characteristics of students that can influence learning outcomes. Cognitive style is a person's usual, common, or preferred way of thinking [32]. The right learning model needs to be adapted to the right thinking strategy. Thinking involves perceiving information, processing information, and applying information. The term cognitive style is used to refer to a person's habitual way of learning or teaching [33]. Cognitive style is different from intellectual ability. Cognitive style refers to the way a person performs. In contrast, intellectual ability refers to a person's level of performance. Researchers believe that a person's cognitive style is consistent over time; however, this may vary across situational contexts. For example, a person may frequently use one cognitive style, but use a different cognitive style to solve problems or handle social situations.

Educators have not yet widely recognized the characteristics of students in the form of cognitive styles in implementing their learning [34]. Based on observations and discussions with social studies educators at SMP Plus Al Fatimah Bojonegoro held in January 2025, it was revealed that so far they have never paid attention to student characteristics in their learning, such as cognitive styles, learning styles, learning motivation, intelligence levels, creativity levels, and so on. Usually, educators only pay attention to aspects of models, methods, and media applied to social studies subject matter..

In addition to not paying attention to the cognitive style aspect in learning, social studies educators also "almost" never use maps as a media for social studies learning, even though they realize that maps are the most representative media in displaying symptoms of both social and physical phenomena on the surface of the Earth. Any social phenomenon that occurs on the surface of the Earth can be expressed through maps such as population distribution maps, political maps (election/regional election results), disaster-prone area maps, tourism maps, economic level maps, and so on. The low use of maps also makes spatial abilities low. The results of interviews with three eighth-grade students at SMP Plus Al Fatimah on January 17, 2025, showed that they had difficulty reading maps, when given a map of East Java they could not indicate which areas were prone to tsunamis, landslides and floods, they also did not know which areas in their area (Bojonegoro) were prone to flooding.

A frequently encountered and recurring problem in the social studies learning process is how to make it easily understood and engaging for students [35]. To improve the effectiveness and spatial abilities of map-based learning in social studies, efforts are needed to improve educator skills and the availability of quality map-based learning materials [36]. In addition, actively involving students in the PBL model in the learning process and ensuring good integration with the curriculum can help overcome some of these obstacles. Therefore, researchers assume that the learning implemented so far has not contributed to a complete understanding of social studies material for students, considering the reality of social studies learning implemented so far using a multidisciplinary approach where learning of scientific fields is separated. Meanwhile, social studies subjects have a relationship and continuity of material on space and territory (spatial) with other materials through an interdisciplinary approach.

2. Methods

This study used a quasi-experimental approach with a 2x2 factorial design. The subjects were eighth-grade students at SMP Plus Al-Fatimah Bojonegoro. The sample was purposively selected, consisting of 62 students in the experimental class and 60 students in the control class. There were two main treatments: (1) learning model (map-assisted PBL with an interdisciplinary approach and Direct Instruction), and (2) cognitive styles (Field Dependent and Field Independent).

The instrument used was a test administered before and after the treatment (pretest and posttest). The test was used to determine the outcome of the treatment. The test consisted of 10 essay questions, each scored between 0 and 5, resulting in a maximum score of 50. The learning outcome score was calculated by dividing the total score by 5 and then multiplying by 10. Therefore, if a student obtained a perfect score, their learning outcome would be 100. The research data analysis used the results obtained from the posttest.

The test instrument consists of a spatial ability test consisting of a pretest and posttest, a critical thinking test consisting of a pretest and posttest, and a GEFT (Group Embedded Figures Test) questionnaire to determine cognitive styles. The instruments used consist of: 1) a Spatial ability test. The spatial ability test consists of 7 questions arranged based on the indicators compiled by Prasetya, et al. [35]. Thinking Ability Test (STAT) compiled by Prasetya, et al. [35], there are seven factors that influence the formation of spatial abilities in a person, namely: Comparing objects, Identifying object characteristics, Classifying object locations, Showing object locations, Analyzing phenomena, Synthesizing phenomena, Predicting geosphere phenomena..

The critical thinking ability test is adapted from the Critical Thinking Instrument Test (CTIT) developed by Havelková and Hanus [36]. The CTIT instrument refers to five aspects of critical thinking: 1) Interpretation, namely the ability to understand and interpret information accurately. For example, explaining the meaning of graphs or data, 2) Analysis, namely the ability to identify arguments, reasons, and evidence. For example, analyzing the relationship between variables or components of a problem, 3) Evaluation, assessing the credibility of information and the strength of an argument. For example, determining whether a reason is valid or not, 4) Inference, drawing logical conclusions from existing data or information. For example, predicting results based on patterns or data, 5) Explanation, expressing opinions and logical justification for decisions or conclusions. For example, explaining why a hypothesis can be accepted.

The cognitive style questionnaire used is the Group Embedded Figures Test (GEFT). The GEFT used in this study was developed by Gersmehl and Gersmehl [37] and Ennis [38]. This test is used to measure students' ability to find a simple shape hidden in a complex pattern. This picture-shaped test consists of three parts: the first part includes seven pictures, and the second and third parts each consist of nine pictures. The first part is for practice, so the results are not counted as cognitive style. The time allocation for working on the first part is two minutes. The second and third parts are the actual cognitive style tests, where the time allocated to complete the two parts is five minutes each, with the following scoring provisions: correct answers are given a score of 1, wrong answers are given a score of 0, and the maximum score is 18. To determine groups of students who have Field Dependent cognitive styles and Field Independent cognitive styles, scores of 0 to 9 are categorized as the Field Dependent group, and scores of 10 to 18 are categorized as the Field Independent group.

Before implementation, the instrument was validated by learning experts and material experts. The learning experts gave an average score of 86, which is in the very good category, and the material experts gave an average score of 90, which is in the very good category. In addition to expert validation, the validity of this instrument has been tested through product-moment correlation, while its reliability has been tested using Cronbach's Alpha. The results of the instrument test show that the items are valid and reliable, as presented in Table 1.

Table 1.
Results of Instrument Validity and Reliability Tests.

Instrument	Sub-indicator	Rcount	Rtable	Decision	Reliability
Spatial abilities	comparing objects	0.8875	0.361	Valid	0.876
	Identify the characteristics of the object	0.866	0.361	Valid	
	Identifying object characteristics	0.825	0.361	Valid	
	shows the location of the object	0.757	0.361	Valid	
	Synthesizing phenomena	0.821	0.361	Valid	
	predicting geospheric phenomena	0.794	0.361	Valid	
Think critically	Interpretation	0.798	0.361	Valid	0.855
	Analysis	0.824	0.361	Valid	
	Evaluation	0.824	0.361	Valid	
	Inference	0.689	0.361	Valid	
	Explanation	0.798	0.361	Valid	

The prerequisite test was conducted using the normality test using the Saphriro-Wilk and Kolmogorov-Smirnov Tests and the homogeneity test using Levene's Test. If the data were normal and homogeneous, the hypothesis test was continued. Data analysis was carried out using a two-way MANOVA to see the main effects and interactions between variables.

3. Results and Discussion

3.1. Result

3.1.1. The Influence of the PBL Model on Spatial Ability

This study involved 122 students divided into two groups based on the learning model: map-assisted PBL (62 students) and conventional learning (60 students). Furthermore, participants were categorized according to their cognitive styles: 58 students were Field Independent (FI) and 64 students were Field Dependent (FD). Posttest spatial ability scores were analyzed based on a combination of learning model and cognitive style. The mean scores and standard deviations are as follows.

Table 2.
Posttest scores of spatial ability.

Learning model	Cognitive Style	N	Mean	Std. Deviation
Map-Assisted PBL	Field Independent	32	82.19	11.70
Map-Assisted PBL	Field Dependent	30	75.83	12.67
Conventional	Field Independent	26	79.42	8.98
Conventional	Field Dependent	34	64.41	9.75

The main findings are that the highest spatial ability score was obtained by the PBL-FI group (82.19), and the lowest score was in the Conventional-FD group (64.41). Overall, the PBL model was superior to the conventional, and the Field Independent cognitive style was superior to the Field Dependent.

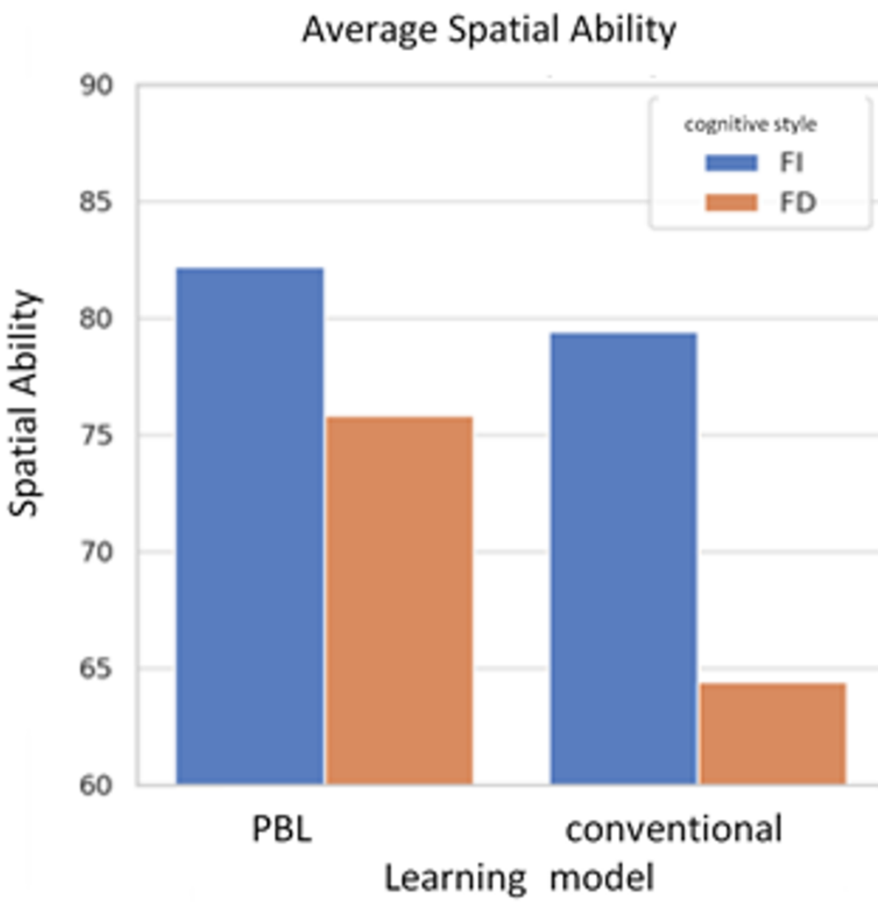

Figure 1.
The value of spatial ability from the combination of learning models and cognitive styles.

The results showed that students taught using the map-assisted PBL model had higher spatial ability scores than the control group. This suggests that map visualization can clarify the understanding of spatial concepts in social studies.

3.1.2. The Influence of the PBL Model on Critical Thinking

The average posttest scores for critical thinking skills based on the combination of learning models and cognitive styles. The average scores and standard deviations are as follows.

Table 3.
Critical Thinking Posttest Value.

Learning model	Cognitive Style	N	Mean	Std. Deviation
Map-Assisted PBL	Field Independent	32	78.06	7.01
Map-Assisted PBL	Field Dependent	30	78.53	8.90
Conventional	Field Independent	26	74.19	9.55
Conventional	Field Dependent	34	74.59	9.00

Main findings: The highest average critical thinking score was found in the PBL-FD group (78.53), but was not much different from the PBL-FI group. The PBL model provided higher results than the conventional model in critical Thinking. Cognitive style did not have a significant effect on critical thinking scores compared to spatial ability.

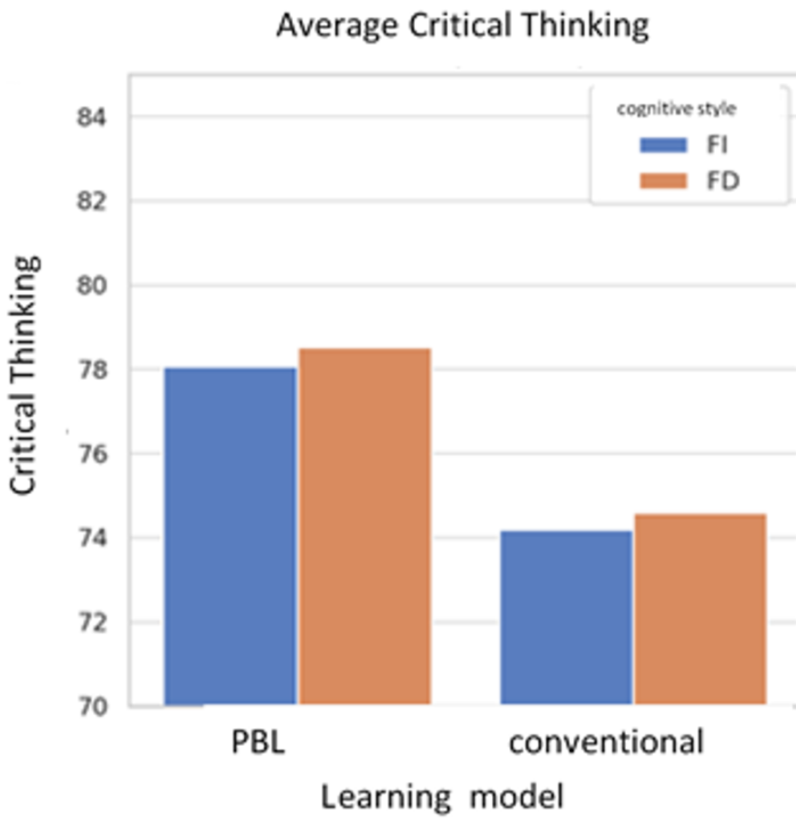

Figure 2.
The value of critical Thinking from a combination of learning models and cognitive styles

PBL encourages students to investigate and present problems. They become more involved in analysis, synthesis, and evaluation, thus enhancing their critical Thinking. The implementation of map-based projects allows students to interpret information in depth.

3.1.3. Interaction of Learning Models and Cognitive Styles

Before conducting the hypothesis test, prerequisite tests were conducted, namely, data normality and homogeneity. The calculation results are as follows. Normality tests were conducted using the Kolmogorov-Smirnov and Shapiro-Wilk tests on three variables: the GEFT Score (cognitive style), the Spatial Ability Posttest, and the Critical Thinking Posttest.

Table 4.
Data normality test.

Variable	Kolmogorov-Smirnov Sig.	Shapiro-Wilk Sig.
GEFT Score	0.088	0.102
Spatial ability	0.087	0.084
Critical Thinking	0.107	0.092

The interpretation of the normality test is that all significance values are > 0.05, both in Kolmogorov-Smirnov and Shapiro-Wilk. This indicates that the data is normally distributed in all three variables.

Levene's test is used to determine whether the variance between groups is homogeneous.

Table 5.
Data homogeneity test.

Variabel	F	Sig.
Spatial ability	1.865	0.139
Critical Thinking	1.394	0.248

The interpretation of the data homogeneity test is a significance value > 0.05 for both variables. This means that the variance between the groups is homogeneous (not significantly different). Therefore, the assumption of homogeneity of variance is met. Therefore, the assumptions of normality and homogeneity are met, and parametric analysis (such as MANOVA) can be used.

Table 6 is the calculation result of the MANOVA test, which examines the influence of learning models (map-based and conventional PBL) and cognitive styles (field dependent & field independent) on spatial abilities and critical Thinking.

Table 6.
Tests of Between-Subjects Effects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Spatial Ability Posttest	5993.557[a]	3	1997.852	16.772	0.000
	Critical Thinking Postest	463.278[b]	3	154.426	2.076	0.107
Intercept	Spatial Ability Posttest	687899.458	1	687899.458	5775.065	0.000
	Critical Thinking Postest	704039.704	1	704039.704	9466.765	0.000
Learning_model	Spatial Ability Posttest	1519.307	1	1519.307	12.755	0.001
	Critical Thinking Postest	461.123	1	461.123	6.200	0.014
Cognitive_Style	Spatial Ability Posttest	3446.288	1	3446.288	28.932	0.000
	Critical Thinking Postest	5.672	1	5.672	.076	0.783
Learning_model * Cognitive_Style	Spatial Ability Posttest	565.817	1	565.817	4.750	0.031
	Critical Thinking Postest	.042	1	.042	.001	0.981
Error	Spatial Ability Posttest	14055.623	118	119.115		
	Critical Thinking Postest	8775.615	118	74.370		
Total	Spatial Ability Posttest	707800.000	122			
	Critical Thinking Postest	721073.000	122			
Corrected Total	Spatial Ability Posttest	20049.180	121			
	Critical Thinking Postest	9238.893	121			

Note: a. R Squared = 0.299 (Adjusted R Squared = 0.281)
b. R Squared = 0.050 (Adjusted R Squared = 0.026).

Based on the results of the hypothesis test calculations with MANOVA in table 6, it can be concluded that Spatial ability shows a significant influence from the learning model (F = 12.755, p = 0.001), cognitive style (F = 28.932, p = 0.000), the interaction of model and cognitive style (F = 4.750, p = 0.031). Critical Thinking is only significantly influenced by the learning model (F = 6.200, p = 0.014), while cognitive style and the interaction of the two are not significant. There is a significant interaction between the learning model and cognitive style on spatial ability and critical Thinking. The PBL model is most effective when given to students with a Field Independent style, because they are able to explore and synthesize information more actively.

3.2. Discussion

3.2.1. The Influence of Learning Models on Spatial Ability

The results of the study showed that the learning model had a significant influence on students' spatial abilities (F = 12.755; p = 0.001). The average spatial ability score of students taught using the map-assisted Problem Based Learning (PBL) model was higher than that of students taught using the conventional model. This indicates that map-assisted PBL is able to provide a more meaningful, contextual learning experience and requires students to be actively involved in the spatial exploration process.

The PBL model encourages students to identify real-world problems related to space and territory, then solve them through group work and the use of maps as a spatial visualization tool. This visualization is crucial in the formation of spatial concepts such as location, distance, direction, and spatial relationships [39]. This aligns with Witkin [40] and Jonassen and Rohrer-Murphy [41] argument that problem-based learning can improve higher-order thinking skills and conceptual understanding through active engagement in contextual problem-solving.

The Problem-Based Learning (PBL) model is a learning strategy that places students at the center of the learning process by posing, understanding, and solving real-life problems relevant to their lives [42]. In the context of Social Studies learning, particularly those related to space and territory, this approach is highly effective in developing higher-order thinking skills, particularly spatial and critical thinking abilities [43]. Through PBL, students are confronted with problematic situations stemming from real-life geographic phenomena, such as traffic congestion in urban areas, flooding due to land conversion, development inequality between regions, or the unequal distribution of natural resources. These problems not only encourage students to understand theoretical concepts but also require them to analyze the interrelationships between space, human activity, and the physical environment.

The use of maps as a visualization tool is an essential element of this approach. Maps enable students to understand the spatial dimensions of the problem being studied—such as location, distribution, relationships between regions, and the potential and constraints of a space [44]. Through thematic maps, image maps, or digitally processed maps, students can visually see the relationship between geographic data and socio-economic conditions, thereby strengthening their spatial mental representation [45]. Furthermore, spatial visualization through maps helps students track hidden geographic patterns or trends, interpret scale and proportion more accurately, build accountable, evidence-based arguments, and develop contextual solutions to specific regional problems. Implementing a map-assisted PBL model not only fosters strong conceptual understanding but also fosters practical skills in reading, interpreting, and using spatial information functionally. This transforms social studies learning into more than just rote learning, but also a means of developing critical, reflective citizens capable of contributing to solving real-world problems in their environment.

3.2.2. The Influence of Cognitive Style on Spatial Ability

The data also showed that cognitive style significantly influenced students' spatial abilities ($F = 28.932$; $p = 0.000$). Students with a Field Independent (FI) cognitive style obtained higher scores compared to Field Dependent (FD) students. FI individuals tend to be able to process information analytically, separate primary information from background information, and are more independent in decision-making when completing spatial tasks.

In the context of geography and mapping learning, the ability to independently analyze map symbols, legends, and orientation is crucial. This explains why FI students excel in spatial understanding. These results reinforce the findings of Witkin and Goodenough [46] who stated that individuals with an FI style excel at tasks that require visual and analytical skills. In geography learning, maps are not merely visual aids but complex spatial representation tools [47]. Maps contain a variety of information in the form of symbols, legends, orientation, scale, and other cartographic elements [48]. Being able to read and analyze these elements independently is a fundamental skill in building a comprehensive spatial understanding [49]. The ability to accurately interpret map symbols and legends requires students to understand visual abstraction [50, 51]. They must recognize that each symbol represents a real-world object or phenomenon, and that the legend is key to correctly interpreting these symbols. Furthermore, map orientation, including cardinal directions and coordinate systems, forms the basis for understanding the relative and absolute position of a location on the Earth's surface. This process requires detailed analysis and logical Thinking—the ability to relate spatial information in a broad, cross-dimensional context.

Students with a Field Independent (FI) cognitive style tend to excel. They are characterized by independent, analytical learning, and a reduced reliance on external context [52]. When presented with a map, FI students can immediately focus on the structure and content of the map itself without requiring much assistance or guidance from the teacher or group members. They are better able to extract information from complex symbols, interpret legends quickly, and use directional orientation with high precision to analyze location and distance.

This independence makes FI students superior in understanding spatial representations comprehensively [53]. They tend to be quick at constructing mental maps—cognitive representations of geographic space—which enable them to interpret and navigate maps more efficiently. With this advantage, they are not only better equipped to understand complex spatial concepts but also able to use spatial information critically and strategically, for example, in spatial problem-solving, regional planning, or geospatial analysis. In contrast, students with a Field Dependent (FD) learning style may require more assistance from the social context, teacher guidance, or other explicit learning media. This suggests that in geography and mapping learning, selecting learning strategies that consider students' cognitive styles is crucial so that all students, both FI and FD, can develop optimally. Thus, FI students' superiority in spatial understanding does not arise by chance, but rather is the result of their cognitive tendencies that match the characteristics of cartographic tasks that require detailed analysis, independent learning, and symbolic thinking skills.

3.2.3. Interaction of Learning Models and Cognitive Styles on Spatial Ability

The interaction between learning model and cognitive style also showed a significant effect on spatial ability ($F = 4.750$; $p = 0.031$). This indicates that the effectiveness of the learning model is inseparable from individual cognitive characteristics. For example, the combination of the PBL model and the FI cognitive style produced the highest score, while the combination of the conventional model and the FD style produced the lowest score. This means that the use of innovative learning models such as PBL will be more optimal if it considers student characteristics, especially cognitive styles. In this case, teachers need to conduct an initial assessment of student learning styles to design appropriate learning interventions.

The use of innovative learning models such as Problem-Based Learning (PBL) has been shown to significantly contribute to improving students' critical thinking skills, problem-solving skills, and conceptual understanding [54]. However, the effectiveness of this model's implementation cannot be separated from the individual characteristics of students, particularly their cognitive styles. PBL, as an approach that emphasizes independent, exploratory, and collaborative learning, is more optimal when tailored to students' preferences and ways of Thinking.

One important aspect influencing the success of PBL implementation is the Field Independent (FI) and Field Dependent (FD) cognitive styles [55]. Learners with an FI style tend to be more independent in processing information, able to analyze important elements in complex situations [56] and better prepared to complete open-ended tasks such as those offered by the PBL model [57]. On the other hand, learners with an FD style are more dependent on the external context and require a more directed learning structure and more intensive interpersonal support [58]. This fact indicates that the PBL model is not necessarily suitable for uniform application to all learners without considering their cognitive profiles. Therefore, it is important for teachers to conduct an initial assessment of learners' cognitive or learning styles before designing learning interventions. This assessment can be conducted through instruments such as the Group Embedded Figures Test (GEFT) or other relevant methods to determine learners' tendencies in receiving and processing information.

The results of this assessment not only help teachers in selecting appropriate learning strategies, but also serve as a basis for: Arranging heterogeneous learning group composition in PBL activities, providing adaptive learning support (scaffolding) for students with FD styles, and optimizing the potential of students with FI styles through exploratory tasks and challenging problem solving. Thus, the implementation of the PBL model will be more effective if it is carried out based on diagnostic data about students. This step reflects the application of the principle of differentiated and responsive learning to the diversity of learning styles, which is one of the important pillars in the practice of learner-centered education (learner-centered instruction). The implications of these findings also emphasize the need to strengthen the capacity of teachers in conducting simple psychopedagogical assessments to support more contextual and targeted learning designs.

3.2.4. The Influence of Learning Models on Critical Thinking Skills

For the critical thinking variable, the learning model also had a significant effect (F = 6.200; p = 0.014). Students who learned with map-assisted PBL demonstrated higher levels of critical Thinking compared to those who learned conventionally. This occurs because PBL requires students to identify problems, analyze information from various sources, and systematically develop solutions, which are core critical thinking skills.

The use of maps in a PBL context adds depth to students' Thinking because they must interpret spatial data and relate it to the socio-geographical context. This reinforces Mastuti, et al. [59] argument that critical Thinking encompasses interpretation, analysis, evaluation, and inference, all of which emerge in PBL implementation. In the context of Problem-Based Learning (PBL), the use of maps as visual aids is not only instrumental but also strategic in stimulating students' depth of thinking [60]. PBL encourages students to explore real-world, contextual, and open-ended problems, which in geography learning are often closely related to space, location, and spatial relationships [61]. This is where maps play a crucial role as visual representations of complex spatial data. When students interact with maps, they are not simply reading images or symbols but are trained to interpret patterns, distributions, spatial relationships, and changes in regions over time. This process involves higher-order thinking skills, such as analysis, synthesis, and evaluation. They learn to recognize the relationship between spatial data (e.g., population distribution, transportation networks, land use) and broader socio-geographic contexts, such as development inequality, potential resource conflicts, or the impacts of climate change.

Maps serve as a learning media that unites spatial and social dimensions within a single study [62, 63]. Students are challenged to interpret the meaning behind data visualizations and then relate them to relevant social issues, such as regional poverty, migration, or disaster vulnerability [64]. In this process, they develop not only spatial thinking skills but also reflective and critical thinking skills regarding social conditions. Furthermore, when used in PBL-based group activities, maps also serve as collaborative tools that encourage discussion, argumentation, and shared decision-making. For example, in designing urban spatial planning solutions or disaster mitigation, students need to agree on interpretations of spatial data and align them with contextual socio-economic approaches. The use of maps in a PBL approach not only reinforces the visual aspect but also enriches analytical thinking processes and spatial-social synthesis. This reinforces the idea that mapping in education is not merely technical but also imbued with cognitive and pedagogical meaning that can broaden students' perspectives on space and the dynamics of life within it.

3.2.5. The Influence of Cognitive Style on Critical Thinking Ability

The results of the study showed that cognitive style did not significantly influence students' critical thinking skills (F = 0.076; p = 0.783). This finding indicates that differences in cognitive preferences, both Field Independent (FI) and Field Dependent (FD), do not substantially differentiate students' levels of critical thinking skills when they are given the same learning intervention. In other words, cognitive style is not a major determinant in the development of critical thinking skills, at least in the context of learning with a Problem-Based Learning (PBL) approach.

This phenomenon suggests that learning strategies have a greater influence on the development of critical thinking skills than students' cognitive characteristics. This finding aligns with Tam [65] statement, which states that the PBL model provides a learning framework that facilitates all students to engage in higher-order thinking activities, such as identifying problems, asking questions, evaluating evidence, formulating arguments, and drawing conclusions. These activities are designed to encourage active, collaborative, and reflective engagement—components that inherently support the development of critical Thinking. This is because the learning structure in PBL is open and supports diverse ways of thinking [62, 66].

The differences in cognitive styles that typically influence conventional learning situations become relatively neutral in this context. According to Anderson, et al. [67] FI students, who typically excel at working independently and analytically, and FD students, who tend to require social support and external context, both have the opportunity to develop their critical thinking skills through group activities and collaborative problem-solving. Thus, it can be concluded that PBL functions as an instructional strategy capable of bridging the disparity in cognitive styles in the development of critical Thinking.

The role of teachers in designing challenging and meaningful learning scenarios is more crucial in activating students' critical thinking skills compared to their cognitive style tendencies [68]. This finding emphasizes the importance of focusing on adaptive instructional design based on higher-order thinking tasks, rather than focusing too much on individual learning style classifications that may not have a significant impact on all types of learning. Critical thinking activities are likely more strongly influenced by learning strategies than by cognitive styles. In other words, PBL is able to bridge differences in cognitive styles in developing critical thinking skills, so that the role of cognitive styles becomes less dominant.

3.2.6. The Interaction of Learning Models and Cognitive Styles on Critical Thinking

The analysis results showed that there was no significant interaction between the learning model and cognitive style on students' critical thinking skills ($F = 0.001$; $p = 0.981$). Thus, it can be concluded that the effectiveness of the Problem Based Learning (PBL) model in improving critical thinking skills is consistent, both in students classified as Field Independent (FI) and Field Dependent (FD).

These findings reinforce Daskou and Tzokas [69] argument that PBL has inclusive instructional characteristics, meaning it is able to accommodate diverse ways of Thinking and cognitive approaches of students. In problem-based learning, all students are actively involved in the critical thinking process through the stages of problem identification, information search, group discussion, decision-making, and solution development [70]. This collaborative and contextual activity structure does not rely directly on cognitive styles, as learning is built on a foundation of comprehensive exploration and social interaction.

The absence of interaction between learning models and cognitive styles also indicates that PBL can function as an equalizer strategy, allowing students with different cognitive characteristics to still obtain relatively equal benefits in terms of developing critical thinking skills. Both FI students who are accustomed to independent analytical Thinking, and FD students who rely more on social contexts, are facilitated to hone their argumentative, evaluative, and reflective skills through the PBL approach. Thus, these results imply that the application of PBL in learning does not require overly specific adjustments based on students' cognitive styles in the context of developing critical Thinking. Instead, according to Kek and Huijser [71] what is more important is the quality of the PBL scenario design itself, including the complexity of the problems posed, the depth of discussion, and providing space for students to take an active role in learning.

Pedagogically, these results support the idea that contextual and problem-oriented learning are more important in determining the development of critical thinking skills than innate cognitive factors. Therefore, teachers need to place greater emphasis on selecting constructivist, open-minded, and collaborative learning approaches, rather than focusing too much on adapting to individual learning styles, which may not significantly impact all competency domains.

4. Conclusion

Based on the analysis and discussion of the influence of learning models and cognitive styles on students' spatial and critical thinking skills, the following conclusions were reached.1) The map-assisted Problem-Based Learning (PBL) model proved more effective than conventional models in improving

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students' spatial and critical thinking skills. This indicates that the use of a problem-based approach and map media encourages students to be more active, exploratory, and analytical; 2) Cognitive style significantly influenced spatial skills, with students with a Field Independent (FI) style performing better than those with a Field Dependent (FD) style. However, there was no significant effect of cognitive style on critical thinking skills, indicating that the development of critical thinking skills can be achieved by all cognitive styles if supported by appropriate learning strategies; 3) There was a significant interaction between learning models and cognitive styles on spatial skills, but no significant interaction on critical Thinking. This means that the effectiveness of learning models on spatial skills is influenced by students' cognitive styles, while their effect on critical Thinking is uniform regardless of cognitive style.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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