



## Understanding the Synergistic Effects of Ecoliteracy and Spatial Literacy on Students' Environmental Problem-Solving Abilities

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**Abstract:** This study aims to analyze the levels of ecoliteracy, spatial literacy, and environmental problem-solving ability among high school students in Medan City, as well as to examine the influence of ecoliteracy and spatial literacy on students' environmental problem-solving abilities. This research employed a correlational design using a survey approach. The participants consisted of 343 high school students in Medan City, selected through proportional random sampling. The research instruments included tests and questionnaires. The ecoliteracy test instrument for the environmental knowledge dimension and the spatial literacy test were scored dichotomously, while the ecoliteracy questionnaire measuring environmental care attitudes and environmental problem-solving ability was assessed using a Likert scale. Data were analyzed using SEM-PLS analysis with SmartPLS 3 software. The results showed that: (1) ecoliteracy had a significant effect on students' environmental problem-solving ability, as indicated by a t-statistic value of 11.378 and a p-value of 0.000; (2) spatial literacy also had a significant effect on environmental problem-solving ability, with a t-statistic value of 9.093 and a p-value of 0.000; and (3) ecoliteracy and spatial literacy jointly contributed 56.4% to students' environmental problem-solving ability, which is categorized as moderate. This study provides empirical evidence that ecoliteracy and spatial literacy are two complementary constructs in shaping students' environmental problem-solving abilities. Through the integration of these competencies and the use of geospatial technology, students can develop evidence-based and contextual solutions, enabling them to become a generation that is responsive to real-world environmental challenges such as climate change and other complex environmental issues.

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### Introduction

The environmental damage that occurs over time is also influenced by human development in fulfilling their needs and desires for the environment. This is in line with the statement put forward by Suharja et al. (2023) that environmental damage is based on human needs and desires for the environment to provide and sustain human life, without regard for the environmental damage that occurs and without consideration for how to manage natural resources, which impacts the environmental balance itself.

Environmental problems also occur in Medan City, namely waste, air pollution, and land conversion. Waste accumulation is a serious problem in environmental management in Medan City. According to data from the Environmental Agency, Medan City produces approximately 2,000 tons of waste daily, approximately 800 tons of which ends up in landfills. This demonstrates the crucial importance of waste management in a city or region.

Proper waste management in a city will also contribute to a healthy urban environment. Conversely, poor waste management can lead to various environmental problems (Harjanti & Anggraini, 2020). This problem also occurs in the Jos Metropolitan, Nigeria, where more than 70% of people claim to be aware of environmental issues, only 65.9% claim to have adequate knowledge, and the participation rate has actually decreased drastically to only 30% who actually apply their knowledge into concrete waste management practices (Akintunde et al., 2024). Low levels of environmental literacy in society result in a lack of desire or capacity to transform evolution and abstract knowledge into everyday behavior.

A study of the BRICS countries (Brazil, Russia, India, China, and South Africa) from 1990 to 2023 found that the influence of education on environmental sustainability is non-linear. Education in other developing cities, is still oriented toward memorization and grades. as a result, these urban communities are stuck in the initial stage, where increasing consumption is characterized by high volumes of waste, unbalanced by the capacity for responsible waste management (Zhang & Xiao, 2025).

Addressing environmental damage is crucial and requires the involvement of the community, especially students. Education plays a role in shaping students who understand environmental issues and are actively involved in solving them, both locally and globally (Rusmana et al., 2021). Several studies have shown that students' environmental problem-solving ability are considered inadequate. This is thought to be due to students' low levels of ecoliteracy (Prastiwi et al., 2020). Ecoliteracy involves understanding and knowing about nature and how its systems operate. It also encompasses an individual's ability to understand the environment and strive to preserve it. This encompasses knowledge of ecological systems, environmental awareness, and actions taken related to the environment (Wijaya & Dewi, 2021).

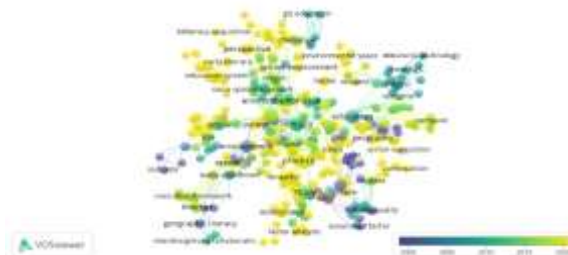
Besides ecoliteracy, spatial intelligence then forms the foundation for developing spatial literacy. Spatial literacy is an individual's ability to capture and communicate knowledge in the form of maps, understand and recognize the world as seen from above (images), and recognize and interpret patterns (Bednarz & Kemp, 2011). Students in high schools who have received geography lessons can mean that they already have ecoliteracy obtained from learning at school so that they are considered capable of solving environmental problems in their area.

Several studies are still lacking that examine the relationship between ecoliteracy and students' spatial literacy and environmental problem-solving abilities, as evidenced by the Vosviewer visualization image from a Scopus search. Figure 1 shows that research on ecoliteracy and environmental problem-solving abilities is still understudied, as seen in the small number of nodes in the visualization. Discussions on ecoliteracy and environmental problem-solving abilities received more frequent discussion and attention between 2012 and 2022.



**Figure 1. Frequency Visualization of Research Years of the Ecoliteracy and Environmental Problem-Solving Abilities**

Figure 2 shows the results of a search of scopus data, identifying 223 articles that met the research criteria based on the keyword "spatial literacy and environmental problem-solving." Previous research has focused on only one variable. Therefore, no previous research has simultaneously integrated ecoliteracy and spatial literacy into environmental problem-solving skills using SEM-PLS. Based on the visualization, the most recent year to discuss spatial literacy is 2020. This definition indicates that the topic of spatial literacy and environmental problem-solving abilities is still relatively new.



**Figure 2. Frequency Visualization of Research Years of the Spatial Literacy and Environmental Problem Solving Ability**

Based on this, the originality of this research lies in the integration of ecoliteracy with aspects of knowledge and attitudes, spatial literacy with aspects of spatial habits of mind, concepts, and critical spatial thinking as dual predictors of environmental problem-solving abilities. This study was conducted to analyze the influence of ecoliteracy and spatial literacy on students' environmental problem-solving abilities in high schools in Medan City. This research can serve as a basis for developing learning that leads to the development of students' environmental problem-solving abilities.

### Research Method

This research is a correlational study using a survey. The data obtained were then analyzed using SEM-PLS (Structural Equation Modeling Partial Least Squares). SEM-PLS is a multivariate analysis technique that combines factor analysis and path analysis. This research was conducted at high schools representing districts affected by environmental problems in Medan City: SMA Negeri 11 Medan, SMA Negeri 12 Medan, SMA Negeri 14 Medan, SMA Negeri 15 Medan, SMA Negeri 16 Medan, SMA Al Ulum Terpadu Medan, SMA Al Hikmah Medan, SMA IT Unggul Al Munadi Medan, SMA Kartika 1-2 Medan, SMA Parulian 2 Medan. This is considered representative because these schools represent each sub-district administration with the highest environmental problems.

Total population in this study was 2,418, consisting of 11<sup>th</sup> grade students from ten high schools in Medan City. The sample in this study was determined using the Slovin formula, with a 95% confidence level. Based on calculations using the slovin formula, total sample of 343 students was obtained. The sampling method used was proportional random sampling, with samples drawn from each subpopulation, the number of which was adjusted to the number of members in each subpopulation, randomly. The goal was to obtain a representative sample of high school students in Medan City. The sample size began with a proportional calculation, followed by random selection by recording the names and serial numbers of students from each school. Then, using Excel with the random number generator followed by a sequence of 1 to the total population of each school.

The data collection technique used in this study was a survey using test instruments and questionnaires. The instrument was developed through expert adaptation, the ecoliteracy test and questionnaire were based on indicators from McGinn (2014), the formulation of the spatial literacy test was based on indicators from Minsung (2011), and the questionnaire on

students' environmental problem-solving abilities was based on indicators from Chang, (1998). The ecoliteracy test instrument for the environmental knowledge dimension and the spatial literacy were scored dichotomously, which 1 (correct) and 0 (false). The ecoliteracy questionnaire for the environmental care attitude and environmental problem-solving ability was assessed using a likert scale (4,3,2,1). Data analysis in this study used SEM-PLS with SmartPLS 3 software. Structural Equation Modeling (SEM) Partial Least Squares (PLS) consists of several important aspects: measurement model testing, structural model testing, and model fit testing using *SRMR*. The research model applied in this study is reflective.

The first stage of SEM-PLS consists of a measurement model that determines the influence between latent variables and their indicators. Measurement model testing consists of convergent validity testing. Good validity is achieved if the outer loading value for each indicator is  $>0.70$ . If the convergent validity standard value is  $>0.70$ , loading values below 0.70 are removed from the model. Furthermore, the Average Variance Extracted (*AVE*) value is also examined. The expected *AVE* value to indicate that reliability has been achieved is  $>0.50$ . In addition to validity testing, reliability testing was also conducted. Reliability testing in this study used Cronbach's Alpha and Composite Reliability. The variable is considered reliable if it achieves a reliability value  $\geq 0.7$ .

The second stage of SEM-PLS is structural model testing. Structural model testing can assess the strength and statistical significance of the paths between latent variables. Structural model testing in SEM-PLS plays a key role in examining the influence between latent variables and predicting and explaining their interactions. The structural model consists of processing R-Square values and hypothesis testing. R-square ( $R^2$ ) in SEM PLS is a measure that shows how well the latent variables in the model are able to explain variations in observed observation variables. The hypothesis is proven to be accepted positively or not, if the *t statistics* value is greater than the *t* table value. In addition, it can be seen from the probability value (*p values*) to determine whether the influence value is said to be proven to be accepted significantly or not with a positive or not. The *p values* are said to be significant, if the *p values* are smaller than 0.05 or 5%. Identify the correlation coefficient between the two variables in this study, the researchers used the interpretation of the correlation coefficient according to Ridwan & Kuncoro (2014), as described in Table 1.

**Table 1. Interpretation of the Correlation Coefficient**

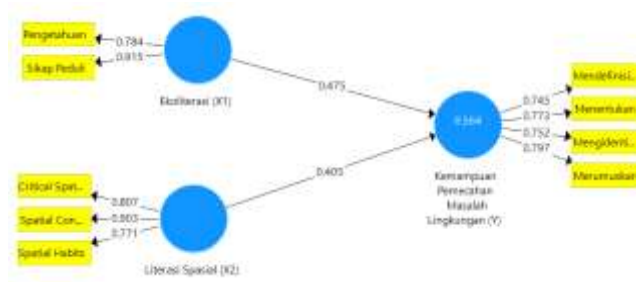
<b>Coefficient Interval</b>	<b>Interpretation</b>
0.00 – 0.199	Very Low
0.20 – 0.399	Low
0.40 – 0.599	Moderate
0.60 – 0.799	Strong

## **Results and Discussion**

### **Measurement Model Evaluation**

#### **1) Convergent Validity**

The convergent validity used in this study is determined by the loading factor results. Loading factor (outer loading) is a coefficient that indicates the strength of the relationship between an indicator and the latent construct it measures in the PLS SEM measurement model. The results of the factor loadings using the Smart PLS 3 application produce the output shown in Figure 3.



**Figure 3. Loading Factor**

Figure 3 shows that each item is valid in measuring the variable, with a loading factor greater than 0.7. Students' ecoliteracy constructs are more strongly reflected in their attitudes and environmental concerns than in their knowledge. This indicates that students with good ecoliteracy not only understand ecological concepts but also demonstrate a caring attitude toward the environment. Students' spatial literacy is primarily influenced by their ability to understand spatial concepts and critical spatial thinking skills. Spatial habits are also relevant, but their contribution is relatively smaller. Students' environmental problem-solving abilities are most strongly reflected in their ability to reflect on and formulate final solutions. However, the entire process, from defining the problem, identifying information, to determining alternative solutions, still reflects the construct well. All ecoliteracy dimensions have excellent validity, this is also outlined in Table 2 below.

**Table 2. Loading Factor Results**

Variable	Dimension	Loading Factor	Criteria
Ecoliteracy (X1)	Environmental Knowledge	0.784	Valid
	Environmental Awareness	0.915	Valid
Spatial Literacy (X2)	<i>Spatial Habits of Mind</i>	0.771	Valid
	<i>Spatial Concepts and Thinking Skills</i>	0.903	Valid
	<i>Critical Spatial Thinking</i>	0.807	Valid
Environmental Problem-Solving Ability (Y)	Defining the Problem	0.745	Valid
	Identifying the Problem	0.752	Valid
	Formulating the Problem	0.797	Valid
	Determining the Problem	0.773	Valid

The next convergent validity test was carried out through average variance extracted (AVE). The average variance extracted test was performed based on the latent variable results. The results of the AVE test using SmartPLS 3 are shown in Table 3. Based on the AVE results, it can be seen that the values obtained for the variables ecoliteracy, spatial literacy and environmental problem-solving ability are more than 0.5, so it can be concluded that all variables meet convergent validity.

**Table 3. AVE Results**

Variable	Average Variance Extracted	Criteria
Ecoliteracy (X1)	0.726	Valid
Spatial Literacy (X2)	0.588	Valid
Environmental Problem-Solving Abilities (Y)	0.687	Valid

## 2) Reliability

Construct reliability was measured using Cronbach's alpha and composite reliability. The results of the second-order reliability test using Smart PLS 3.0 are shown in Table 4.

**Table 4. Composite Reliability dan Cronbach Alpha**

Variable	Cronbach's alpha	Composite reliability
Ecoliteracy (X1)	0.636	0.715
Spatial Literacy (X2)	0.768	0.773
Environmental Problem-Solving Abilities (Y)	0.775	0.821

The reliability test results in Table 4 show that the Cronbach's alpha and composite reliability values for the ecoliteracy, spatial literacy, and environmental problem-solving ability variables are greater than 0.6 and predominantly above 0.7. A Cronbach's alpha value of 0.6 is still acceptable because it is theoretically the lower limit of test score reliability (Sijtsma & Pfadt, 2021). This is reinforced by Zitzmann & Orona, (2025), who emphasized that Cronbach's alpha is not the sole benchmark. Therefore, the composite reliability value of 0.715 has exceeded the acceptable category. Based on Menon et al., (2025) Classification, a value of 0.636 falls into the questionable category, which is still considered acceptable, rather than unacceptable. Therefore, the ecoliteracy, spatial literacy, and environmental problem-solving ability variables can be declared reliable, and this model has a good level of reliability.

### Structural Model Evaluation

Structural model evaluation is an evaluation conducted to test hypotheses and relationships between variables by looking at the path coefficient, t-statistic value, and p-value. The t-statistic is said to have a significant influence between variables if the calculation result is greater than 1.96 (t-table) at a 95% confidence level with a two-tailed test, and the p-value of the test result is less than 0.05. This study will explain the results of the path coefficient test, R-square, and its hypotheses.

#### 1) Path Coefficient

The path coefficient result is used to show the strength of the effect or influence of the independent variable on the dependent variable. The path coefficient results are shown in Table 5.

**Table 5. Path Coefficient**

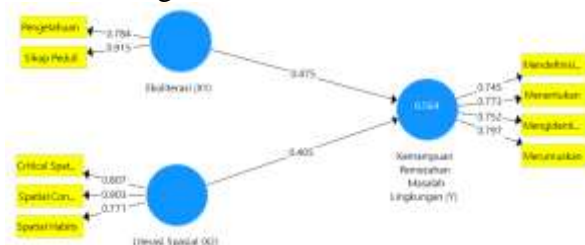
	Original Sample (O)	Mean (M)	Standard Deviation (STDEV)	T-Statistic ( O/STDEV )	P Values
Ecoliteracy (X1) -> Environmental Problem-Solving Abilities (Y)	0.475	0.474	0.042	11.378	0.000
Spatial Literacy (X2) -> Environmental Problem-Solving Abilities (Y)	0.405	0.408	0.045	9.093	0.000

Table 4 presents the test results for several key variables involved in this study, relating to the relationship between ecoliteracy, spatial literacy, and environmental problem-solving abilities. The analysis shows that the relationship between ecoliteracy and environmental problem-solving abilities demonstrates a statistically significant sample value, with a t-statistic of  $11.378 > 1.96$ . Similarly, the relationship between spatial literacy and problem-solving abilities demonstrates a statistically significant sample value, with a t-statistic of  $9.093 > 1.96$ . Thus, the results of this analysis provide a deeper understanding of the strength of the relationship between the variables in the study. The variables ecoliteracy and environmental problem-solving abilities demonstrate a significant impact.

#### 2) R-square test

The coefficient of determination (r-square) is used to measure the extent to which the dependent variable is satisfied by other variables. An  $R^2$  value of 0.67 or above for the

dependent latent variable in the structural model indicates a high influence of the independent variable on the dependent variable. A value of 0.33-0.67 indicates a moderate influence, and a value of 0.19-0.33 indicates a weak influence. Based on data processing using Smart PLS 3, the R-square values are shown in Figure 4 and Table 5.



**Figure 4. R-Square**

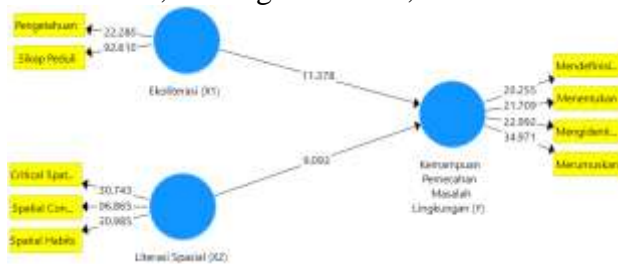
The analysis results obtained an r-square value of 0.607. Figure 4 and Table 6 show the R Square and Adjusted R Square values recorded as an evaluation matrix to the extent to which the model is able to explain variation in the data. The R Square value of 0.564 indicates that the regression model is able to explain approximately 56.4% of the variation in environmental problem-solving ability. The nearly comparable Adjusted R Square value, namely 0.561, indicates the consistency of the model. With the description "moderate", Table 30 shows that the model can moderately explain variation in the level of students' environmental problem-solving ability.

**Table 6. R-Square Results**

	R Square	Adjusted R Square	Category
Environmental Problem-Solving Abilities (Y)	0.564	0.561	Moderate

### 3) Hypothesis Testing (Bootstrapping)

This stage involves hypothesis testing by examining the t-value and p-value of the bootstrapping results. The hypothesis requires that if the t-statistic is greater than 1.96,  $H_0$  is rejected and  $H_1$  is accepted. If the t-statistic is less than 1.96,  $H_0$  is accepted and  $H_1$  is rejected. The significance of the variables tested is illustrated by the value of the arrow connecting one variable to another, the target variable, and the results are shown in Figure 5.



**Figure 5. Structural Model Path Results**

### The Effect of Ecoliteracy on Students' Environmental Problem-Solving Abilities

The first research hypothesis is "ecoliteracy plays a significant role in students' environmental problem-solving abilities." Therefore, based on this hypothesis, the following statistical hypotheses are formulated:

$H_0$ : Ecoliteracy does not play a significant role in students' environmental problem-solving.

$H_1$ : Ecoliteracy plays a significant role in students' environmental problem-solving abilities.

According to Figure 5, the *t-statistic* for ecoliteracy on environmental problem-solving abilities is  $11.378 > 1.96$ , with a p-value of  $0.000 < 0.050$ . This very low p-value indicates there is evidence to reject the null hypothesis. This indicates that ecoliteracy significantly influences changes in students' environmental problem-solving abilities. Therefore,  $H_1$  is accepted, meaning ecoliteracy plays a significant role in students'



environmental problem-solving abilities in Medan City. The original sample value was 0.475. This value shows that the direction of the influence of ecoliteracy on environmental problem-solving abilities is positive or unidirectional, meaning that the higher the student's ecoliteracy, the better the student's environmental problem-solving abilities.

Each unit increase in ecoliteracy increases environmental problem-solving ability by 47%, and this effect is categorized as moderate. This finding aligns with Sigit et al. (2021), who revealed a significant positive relationship between environmental knowledge and the ability to solve environmental pollution problems, with a moderately strong correlation. Factors contributing to students' lack of ecological knowledge include age and intensity of interaction with nature. Students are considered ecologically literate if they possess a basic understanding of ecology and a concern for it, which can be used to develop environmental problem-solving abilities.

Ecoliteracy had a greater impact at 47%, because the curriculum in Medan City is more responsive to environmental issues that are closely related to students' daily lives. A study by Rachman & Matsumoto (2023) revealed the process of developing environmental education textbooks by teachers in Medan, which began by identifying the most crucial environmental problems in the city. The results revealed that waste management was the top issue, followed by river problems, wastewater, and flooding. The curriculum and teaching materials in Medan are consciously designed to build a deep understanding of real-world environmental issues.

Similarly, Syah et al. (2021) found that this can be achieved through the school's Adiwiyata program, which integrates the environment into the learning process and involves students in environmental activities. These activities not only increase student knowledge but also their concern for problem-solving abilities. When answering questions about problem-solving abilities, students must use their existing knowledge and attitudes to address difficult questions or situations. Cremin et al. (2020) stated that the dimensions of students' environmental knowledge and attitudes work together to support their understanding of environmental issues and problems, helping them find effective solutions, which in turn improves their environmental problem-solving abilities. This can also be used as an important indicator of the success of a learning process when students can apply what they have learned in their daily lives.

Research by Putri & Rezanía (2024) also supports the relationship between ecoliteracy and problem-solving abilities. These results shape the ability to take action and improve problem-solving abilities based on knowledge and responsibility. Furthermore, ecoliteracy and problem-solving abilities are also influenced by factors such as motivation, student thinking styles, and learning programs.

### **The Effect of Spatial Literacy on Students' Environmental Problem-Solving Abilities**

The second research hypothesis is "spatial literacy plays a significant role in students' environmental problem-solving abilities." Therefore, the following statistical hypotheses are formulated:

H<sub>0</sub>: Spatial literacy does not play a significant role in students' environmental problem-solving abilities.

H<sub>2</sub>: Spatial literacy plays a significant role in students' environmental problem-solving abilities.

Based on the test results, the *t-statistic* for the relationship between spatial literacy and environmental problem-solving abilities was  $9.093 > 1.96$ , with a p-value of  $0.000 < 0.050$ . This very low p-value indicates there is evidence to reject the null hypothesis. Therefore, H<sub>1</sub> is accepted, meaning that spatial literacy plays a significant role in students' environmental



problem-solving abilities in Medan City. The original sample obtained a p-value of 0.405. This value indicates that the direction of the influence of spatial literacy on environmental problem-solving abilities is positive or unidirectional, meaning that higher spatial literacy, better environmental problem-solving abilities.

Each unit increase in spatial literacy improves environmental problem-solving abilities by 40%. Environmental problem-solving abilities require a deep understanding of the complexity, interdependence, and dynamics of natural systems. This is where spatial literacy plays a central role. This aligns with the findings of Shin & Bednarz (2018), who assert that spatial literacy is the ability to use spatial representations and tools to think critically about relationships in space. In the context of environmental problems, individuals with high spatial literacy see more than isolated points like trash. They are able to map the distribution of this trash and analyze it in relation to settlement patterns and the root causes of the problem.

Based on the results above, the 40% increase in spatial literacy is due to the fact that most geography teachers in Medan City teach spatial literacy in a more technical manner, isolated from the context of environmental problem-solving. While spatial-based learning models have not been widely adopted, research Andini et al., (2025) shows they are effective in developing critical thinking skills, particularly in students' environmental problem-solving abilities. If learning focuses more on technical spatial skills, such as reading and creating topographic maps, without connecting them to systemic environmental problem analysis, the impact on environmental problem-solving abilities will not be as significant as more applied ecoliteracy. The findings of Dewi et al., (2025) confirm the t-test results of their study, which showed a significant positive effect between spatial skills and environmental problem-solving abilities. Students involved in problem-based hybrid learning had higher average scores due to their problem-solving reasoning and scientific attitudes developed during the learning process.

### **The Influence of Ecoliteracy and Spatial Literacy on Students' Environmental Problem-Solving Abilities**

The third research hypothesis is "ecoliteracy and spatial literacy play a role in students' environmental problem-solving abilities." Therefore, based on this hypothesis, the following statistical hypotheses are formulated:

H0: There is no influence of the structural model of ecoliteracy and spatial literacy on environmental problem-solving abilities.

H3: There is an influence of the structural model of ecoliteracy and spatial literacy on environmental problem-solving abilities.

This third hypothesis is tested based on the r-square value in the structural model. Table 5 shows that the influence of ecoliteracy and spatial literacy on students' environmental problem-solving abilities is 56.4%, a moderate influence. The remaining 43.6% is influenced by other factors not included in this study.

This study indicates that the model can moderately explain variation in students' environmental problem-solving abilities. These results align with Rimba (2023) findings, which found a combined effect of 0.590 in a high school in Bogor City, also in the moderate category. The remaining 43.6% is explained by factors outside the model, such as intrinsic motivation, leadership, access to technology, or school policy support. The R-square value of 56.4% in this study can be considered adequate and the structural model of ecoliteracy and spatial literacy on environmental problem-solving skills demonstrates a link. These findings confirm that teachers can no longer teach these two aspects separately. Teachers need to adopt learning models such as SPBL (Spatial Problem-Based Learning), as demonstrated in research of Andini et al., (2025), which demonstrated that integrating spatial analysis with



environmental problem-solving significantly impacts students' critical thinking skills, especially those with high levels of ecoliteracy.

The validity of the relationship model between the three constructs justifies the need for contextually designed learning interventions. Innovations such as Lusi Eco-Quest, a geo-game developed by Putra et al., (2025) for mangrove conservation learning, demonstrate that integrating geospatial technology with local environmental content can create effective learning experiences. Research by Lo Iacono et al. (2024) introduced an innovative approach combining digital maps and spatial simulations to solve environmental problems. This approach offers a new perspective with ecoliteracy and spatial literacy. Teachers also need to utilize learning methods such as project-based learning, simulations, and field studies to address other aspects such as students' motivation, hands-on experience, and emotional intelligence. Prasetyo et al., (2024) showed that the disaster simulation method was quite effective, with an N-Gain value of 60.54%, in improving geography learning outcomes.

Both literacy methods can also be integrated into a single learning module. The developed module adheres to the principle of contextuality, which emphasizes the use of real phenomena in the student's environment as learning resources, as in Pratama et al., (2024) research. Furthermore, inquiry and project approaches can be implemented, consistent with Nurhakim et al., (2017) research, which states that students actively investigate, rather than simply receive information. This aligns with research on the development of inquiry-based Subject-Specific Pedagogy (SSP), which effectively increases ecoliteracy by 51%. It also integrates simple technologies such as the use of base maps and simple mapping applications like Google Earth for spatial analysis. The structural model resulting from this study can provide a clearer understanding of how ecoliteracy and spatial literacy interact and how their combination can enhance individuals' abilities to address and solve complex environmental challenges.

## **Conclusion**

This study successfully demonstrated that ecoliteracy and spatial literacy had a moderate effect on environmental problem-solving ability, amounting to 56.4%. This moderate level can explain variations in ability levels based not only on conceptual knowledge about the environment but also on the ability to manage information spatially. Students' understanding of ecological principles or knowledge of the impact of human activities on the environment. Furthermore, the significant contribution of spatial literacy indicates that the ability to manage, interpret, and use spatial information plays a crucial role in the problem-solving process. The model used provides valid statistical evidence linking the three constructs. Improving ecoliteracy and spatial literacy is an important strategy in environmental learning. Educational efforts that emphasize not only knowledge but also spatial understanding have been shown to strengthen students' abilities to respond to and solve various environmental problems more critically, logically, and based on spatial data.

## **Recommendation**

This study recommends efforts to improve ecoliteracy, spatial literacy, and environmental problem-solving abilities can be achieved by integrating geography learning strategies and models. Teachers can initiate environmental mapping projects for students. Students can then create simple maps of green infrastructure or critical land around the school using QGIS, which can then be analyzed and presented in an interactive WebGIS. Furthermore, teachers can utilize Geoinformation Web-App Technology (GEE)-based tools to enable students to explore maps of disaster risk and land cover change in their area. Using



these tools, students can identify flood or landslide risk zones in their area, understand their causes, and design data-driven mitigation strategies. Schools are advised to establish waste banks so that environmental programs can be implemented routinely and sustainably, including by students. Recommendations for further research include conducting research and development to produce modules and learning platforms that systematically integrate the strengthening of ecoliteracy and spatial literacy, then examining the influence of family environment, community support, access to technology, on environmental problem-solving abilities, and conducting comparative studies between the environmental problem-solving abilities of students in metropolitan cities and students in rural areas.

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