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The Effect of Environment-Based Experiential Learning on Students' Science Literacy and Ecological Awareness

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ABSTRACT

Science literacy and ecological awareness are essential competencies in 21st-century education; however, elementary learning often emphasizes conceptual understanding rather than real-life application, resulting in low student engagement and limited environmental awareness. Previous studies have examined experiential learning or inquiry approaches separately, but comparative studies integrating both cognitive and affective outcomes remain limited. This study aims to analyze and compare the effects of an experiential learning approach grounded in the environment and an inquiry approach on students' science literacy and ecological awareness. This research employed a quantitative posttest-only design involving two experimental groups with a total of 144 elementary students. Data were collected using a science literacy test adapted from the PISA framework, an ecological awareness questionnaire, and a student response questionnaire. Data were analyzed using multiple linear regression. The results show that the experiential learning approach has a significant positive effect on both science literacy and ecological awareness and is more effective than the inquiry approach. In contrast, student responses do not significantly influence learning outcomes. These findings highlight the importance of direct and contextual learning experiences in improving both cognitive and environmental competencies. This study contributes to the development of experiential learning in elementary education and provides practical implications for designing more meaningful and sustainability-oriented learning.

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1. INTRODUCTION

Learning in Natural and Social Sciences (IPAS) at the elementary school level plays an important role in developing scientific thinking skills and fostering environmental awareness from an early age [1]. The demands of the 21st century require students not only to master concepts but also to apply knowledge in real-life contexts. Science literacy is a key competency that involves understanding phenomena, making evidence-based decisions, and solving problems rationally [2]. In addition, ecological awareness is increasingly important due to global environmental issues that require active contributions from younger generations [3]. However, in practice, learning in elementary schools still tends to emphasize conceptual understanding rather than the application of knowledge in real-life environmental contexts. This condition indicates a gap between expected competencies and actual learning outcomes.

Problems observed in the field show that students tend to be passive and less engaged in the learning process. Difficulties arise when students are required to relate concepts to real-world conditions in their surroundings. Teacher-centered learning contributes to low levels of critical thinking skills and environmental awareness [4]. The inquiry approach has been used as an alternative because it encourages discovery processes, yet its implementation remains limited to cognitive aspects [5]. Several studies reveal that inquiry has not optimally enhanced ecological awareness due to a lack of authentic experiences and students' emotional engagement [6]. This finding highlights a research gap: the lack of learning approaches that simultaneously integrate cognitive development, real-world experience, and emotional engagement to foster both Science literacy and ecological awareness.

Empirical data further reinforce the urgency of improving students' Science literacy in Indonesia. Based on PISA (Program for International Student Assessment) data, Indonesian students' Science literacy is categorized as low compared to other countries. A report from the Organization for Economic Co-operation and Development (OECD) shows that in 2018, Indonesia ranked 71st out of 79 countries, with a score of 396 [7]. This condition reflects the limited effectiveness of current learning approaches in helping students apply scientific knowledge in real-life situations, thereby strengthening the need for more context- and experience-based learning innovations.

A review of the literature indicates that the experiential learning approach has great potential to enhance learning quality by treating direct experience as the primary source of knowledge. This model enables students to experience, reflect, understand, and apply concepts in real-life situations [8]. Previous studies show that experiential learning can improve Science literacy through experience-based activities and environmental exploration [9], while other studies indicate its effectiveness in developing ecological awareness through direct interaction with the environment and understanding the impact of human activities [10]. Nevertheless, most previous studies have examined these outcomes separately and rarely compared experiential learning with other approaches within a single experimental design. In addition, the integration of environment-based experiential learning in IPAS at the elementary level remains limited [11]. This indicates a clear research gap that this study seeks to address.

To address these problems, this study proposes implementing an experiential learning approach grounded in the environment, emphasizing direct interaction with the environment across the stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation. This approach is expected to bridge the gap between theory and practice and to strengthen students' cognitive and affective engagement.

The inquiry approach is used as a comparison because it similarly promotes student engagement but differs in its emphasis on direct experience. Through this comparison, this study aims to provide empirical evidence regarding the relative effectiveness of both approaches in improving learning outcomes.

The objective of this study is to analyze and compare the effects of an environment-based experiential learning approach and an inquiry approach on students' Science literacy and ecological awareness. The novelty of this study lies in integrating an environment-based experiential learning approach with a comparative analysis of the inquiry approach within a single experimental design without a control group. The study also examines two dependent variables simultaneously, namely Science literacy and ecological awareness at the elementary school level. Theoretically, this study contributes to the development of constructivist and experiential learning frameworks in elementary science education. In practice, the findings are expected to provide guidance for teachers in designing more contextually relevant and meaningful learning experiences. Furthermore, this study is expected to support sustainable education by fostering students' awareness and responsibility toward the environment.

2. METHOD

The research was conducted at SD PAB 17 Pematang Johar and SD Negeri 101751 Klambir Lima, located in Deli Serdang Regency, North Sumatra Province. This study employed a quantitative approach with a 2-group design without a control group. The research design used was a posttest-only design, in which measurements were taken after each group received the treatment. The research subjects were 144 fifth- and sixth-grade elementary school students, divided into two groups: 72 students in the experiential learning experimental class and 72 in the inquiry experimental class.

The posttest-only design was selected because the study aimed to measure the direct effect of different learning approaches after the intervention, without the potential influence of pretest sensitization that may affect students' responses during treatment. This design is considered appropriate for experimental conditions where prior exposure to test items could bias learning outcomes.

Table 1. Posttest-only design

Group	Treatment	Posttest
Experiment	X	O_1
Experiment	X	O_2

Table 1 presents the posttest-only research design involving two experimental groups. The first group was the experiential learning experimental class, which received the treatment (X) and was then measured through a posttest (O_1). The second group was the inquiry experimental class, which also received the treatment (X) and was subsequently measured through a posttest (O_2). Measurement was conducted only at the final stage after the treatments were administered, so the results reflect the effect of each learning approach on the variables studied.

To ensure group equivalence, both groups were selected based on similar academic levels, grade distribution, and school characteristics. In addition, the classes were selected using a cluster-randomized sampling technique to minimize selection bias. The learning materials, instruction duration, and teacher qualifications were also controlled to ensure that the only difference between groups was the learning approach applied.

Data collection techniques included an essay test instrument for the Science literacy variable, a closed-ended questionnaire for the ecological awareness variable, and a questionnaire on students' responses to the environment-based experiential learning approach. The Science literacy test instrument was adapted from the PISA 2018 Science literacy assessment framework. The assessment developed by the Program for International Student Assessment (PISA) in science literacy comprises three main aspects: Science context, Science knowledge, and Science competencies. These three aspects are interrelated and form the Science literacy framework known as the PISA Framework [12].

Table 2. Aspects of science literacy ability

Aspect	Ability
Science Context	Issues within personal, local/national, or global domains that require knowledge of science and technology.
Science Knowledge	An understanding of key facts, concepts, and explanatory theories that form the scientific basis of knowledge. This includes knowledge about natural phenomena and technological artifacts (content knowledge), knowledge of how such ideas are generated (procedural knowledge), and an understanding of the underlying rationale for these procedures and the justification for their use (epistemic knowledge).
Science Competence	The ability to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence Scienceally.

This test measures students' Science literacy skills, aligned with the indicators of science context, Science knowledge, and Science competencies in accordance with PISA standards. The Science literacy test consists of 10 items, each scored on a scale of 1 to 5, providing a comprehensive overview of students' levels of science literacy.

Table 3. Science literacy assessment rubric

Score	Criteria	Description
5	Very Good (Highly Competent)	The response is complete, accurate, and in-depth. It explains scientific phenomena using appropriate Science concepts, designs valid investigations, or interprets data with strong evidence.
4	Good (Competent)	The response is correct and based on scientific principles, but lacks detail. It explains phenomena correctly, although the argument is not fully developed.
3	Fair (Moderately Competent)	The response shows basic understanding. It only mentions general Science concepts without detail, or the data interpretation is partially correct.
2	Poor (Less Competent)	The response contains fundamental misconceptions in Science concepts. Conceptual understanding is inadequate.
1	Very Poor (Not Competent)	The response is irrelevant, completely incorrect, or merely repeats the question without demonstrating scientific understanding.

The obtained scores are then calculated using a formula with a maximum score of 50. The final score is calculated as follows:

$$Final\ Score\ \frac{Earned\ Score}{Maximum\ Score} \times 100 \quad 1)$$

The final scores are subsequently classified into levels of science literacy according to the established criteria.

Table 4. Classification of science literacy ability levels

Intervals	Classification
>80	Very High
70 – 79	High
60 – 69	Moderate
50 – 59	Low
< 49	Very Low

Ecological awareness was measured using a closed-ended questionnaire instrument that provided predefined answer choices. This questionnaire covered three main aspects, namely ecological knowledge, ecological attitudes, and ecological behavior [13]. The questionnaire consisted of 15 statements and used a Likert scale for assessment. This instrument was used to describe students' levels of ecological awareness in a more structured and measurable way.

Table 5. Ecological awareness assessment scale

Positive Statement		Negative Statement	
Criteria	Score	Criteria	Score
Always	4	Always	1
Often	3	Often	2
Rarely	2	Rarely	3
Never	1	Never	4

The student response questionnaire is used to measure the effectiveness of the applied approaches, namely the experiential and inquiry approaches. The instrument includes five aspects covering interest, motivation, satisfaction, evaluation, and responses [14]. Each statement in the questionnaire is measured on a Likert scale from 1 to 4.

Table 6. Student response questionnaire assessment scale

Criteria	Score
Strongly agree	4
Agree	3
Disagree	2
Strongly Disagree	1

The test and questionnaire data were examined for validity and reliability using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach with SmartPLS

4.0. The evaluation of the measurement model focused on assessing convergent validity, discriminant validity, and construct reliability. Convergent validity was determined based on outer loading values greater than 0.70 and Average Variance Extracted (AVE) values greater than 0.50. Discriminant validity was examined using the Fornell–Larcker criterion and HTMT values below 0.90, indicating that each construct was adequately distinct. Construct reliability was evaluated using Composite Reliability (CR) and Cronbach's Alpha (CA), with values above 0.70 indicating good internal consistency [15].

The results of the validity and reliability analysis indicate that all constructs meet the required criteria. Outer loading values exceeded the acceptable threshold, AVE values were above 0.50, and both Composite Reliability and Cronbach's Alpha values were greater than 0.70, confirming that the instruments are valid and reliable. Discriminant validity was also established, as indicated by acceptable Fornell–Larcker and HTMT values. Detailed results of these analyses are presented in Tables 7 and 8 and are available for further consultation in the Appendix.

Table 7. Convergent validity and construct reliability

Variable	Aspect	Item	Outer Loadings	AVE	CR	CA
Science Literacy	Science Context	SL1	0.865	0.764	0.907	0.846
		SL2	0.879			
		SL3	0.877			
	Science Knowledge	SL4	0.832	0.744	0.921	0.885
		SL5	0.922			
		SL6	0.849			
		SL7	0.845			
	Science Competencies	SL8	0.872	0.779	0.914	0.858
		SL9	0.918			
		SL10	0.857			
Ecological Awareness	Ecological Knowledge	EA1	0.850	0.691	0.899	0.851
		EA2	0.695			
		EA3	0.770			
		EA4	0.846			
		EA5	0.818			
	Ecological Attitudes	EA6	0.857	0.708	0.879	0.793
		EA7	0.786			
		EA8	0.693			
		EA9	0.652			
		EA10	0.758			
	Ecological Behavior	EA11	0.860	0.676	0.893	0.840
		EA12	0.824			
		EA13	0.722			
		EA14	0.696			
		EA15	0.797			
Student Response	Interest	SR1	0.818	0.711	0.880	0.800
		SR2	0.872			
		SR3	0.838			
	Motivation	SR4	0.794	0.671	0.859	0.755

	SR5	0.780			
	SR6	0.880			
	SR7	0.836			
Satisfaction	SR8	0.845	0.709	0.879	0.795
	SR9	0.844			
	SR10	0.830			
Evaluation	SR11	0.874	0.718	0.884	0.804
	SR12	0.837			
	SR13	0.864			
Responses	SR14	0.856	0.734	0.892	0.819
	SR15	0.850			

The analysis results indicate that the measurement model has very good quality, as reflected by outer loadings ranging from 0.652 to 0.922, indicating that all indicators strongly represent their constructs, although some are still within the tolerance threshold and can be retained. The Average Variance Extracted (AVE) values range from 0.671 to 0.779, indicating that each construct explains more than 50% of its indicators' variance and thus meets the criteria for convergent validity. Furthermore, the Composite Reliability (CR) values, which range from 0.859 to 0.921, along with Cronbach's Alpha (CA) values between 0.755 and 0.885, demonstrate a high level of internal consistency, indicating that all constructs are reliable and suitable for further analysis.

Table 8. Discriminant validity

Variable	Aspect	Fornell–Larcker	HTMT
Science Literacy	Science Context → Science Knowledge	0.442	0.511
	Science Context → Science Competencies	0.342	0.399
	Science Knowledge → Science Competencies	0.286	0.320
Ecological Awareness	Ecological knowledge → Ecological Attitudes	0.198	0.239
	Ecological knowledge → Ecological Behavior	0.012	0.096
	Ecological Attitudes → Ecological Behavior	0.219	0.242
Student Response	Interest → Motivation	-0.014	0.068
	Interest → Satisfaction	0.159	0.185
	Interest → Evaluation	0.113	0.139
	Interest → Responses	0.116	0.148
	Motivation → Satisfaction	0.161	0.203
	Motivation → Evaluation	0.220	0.272
	Motivation → Responses	0.149	0.183
	Satisfaction → Evaluation	0.283	0.351
	Satisfaction → Responses	0.251	0.309
	Evaluation → Responses	-0.078	0.115

Ethical considerations were carefully addressed in this study. Permission to conduct the research was obtained from the respective schools. Students participated voluntarily with the consent of their teachers and parents/guardians. All data were collected anonymously, and confidentiality was maintained at all times. The research process ensured that participants did not experience any harm, pressure, or disadvantage during the study.

The data were then analyzed using multiple linear regression analysis to examine the effect of learning approaches and student responses on learning outcomes. The first model used science literacy as the dependent variable to test the contributions of experiential learning based on the environment, an inquiry learning approach, and students' responses to science literacy skills. The second model used ecological awareness as the dependent variable to analyze the effect of the same variables on students' level of environmental concern. Using these two regression models separates the analysis by dependent variable, providing a more specific overview of the most influential factors. This approach also provides deeper insight into the strength of the relationship between the independent and dependent variables within a comprehensive analytical framework.

3. RESULTS AND DISCUSSION

3.1. Results

The analysis of students' science literacy under two learning approaches is presented to provide a comparative overview of the findings.

Table 9. Science literacy ability results

Experiential Learning Approach		Inquiry Learning Approach	
Classification	Frequency	Classification	Frequency
Very High	35	Very High	10
High	20	High	21
Moderate	9	Moderate	19
Low	8	Low	11
Very Low	0	Very Low	11
Total	72	Total	72

The distribution of science literacy scores shows that the experiential learning group performed better than the inquiry group. A total of 55 students in the experiential group fall into the high and very high categories, compared to 31 students in the inquiry group. In contrast, the inquiry group shows a higher frequency in the low and very low categories. This indicates a clear difference in achievement levels between the two approaches.

Table 10. Descriptive statistics analysis

Variable	Group	N	Minimum	Maximum	Mean	Std. Deviation
Science Literacy	Experiential	72	52	100	80.28	14.478
	Inquiry	72	36	94	65.17	13.464
Ecological Awareness	Experiential	72	2	4	2.96	.488
	Inquiry	72	1	4	2.31	.597
Student Response	Experiential	72	2	4	3.01	.517
	Inquiry	72	2	4	2.40	.522

Descriptive statistics further confirm this pattern. The experiential group obtained a higher mean science literacy score (M = 80.28) than the inquiry group (M = 65.17). Similarly, ecological awareness in the experiential group (M = 2.96) is higher than in the inquiry group (M = 2.31). Student responses also show higher scores in the experiential group (M = 3.01) compared to the inquiry group (M = 2.40).

Table 11. Model summary of regression analysis 1

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.479[a]	.230	.219	14.019

Regression analysis results indicate a moderate positive relationship between the predictors and science literacy, with a correlation coefficient of 0.479. The model explains about 23% of the variance, with an adjusted R-square of 0.219; other factors influence the remaining variation. The estimation error of 14.019 suggests a moderate level of prediction deviation in the model.

Table 12. ANOVA[a] of regression analysis 1

Model	Source	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8261.982	2	4130.991	21.020	0.000[b]
	Residual	27710.907	141	196.531		
	Total	35972.889	143			

The ANOVA test confirms that the regression model significantly affects science literacy, with an F-value of 21.020 and a significance level of 0.000. The independent variables contribute more strongly than the residual variation, as shown by the difference in the sums of squares. The model demonstrates adequate explanatory power with a regression mean square of 4130.991, exceeding the residual mean square of 196.531.

Table 13. Coefficients[a] of regression analysis 1

Model	Variable	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
1	Constant	62.665	5.688		11.017	.000
	Learning Approach	14.475	2.716	.458	5.330	.000
	Student Response	1.041	2.265	.039	.460	.646

Regression analysis for science literacy indicates that the model is statistically significant ($F = 21.020$; $p < 0.001$) and explains 23% of the variance ($R^2 = 0.230$). The learning approach has a significant positive effect on science literacy ($\beta = 0.458$; $p < 0.001$), while student response does not show a significant effect ($p = 0.646$).

Table 14. Model summary of regression analysis 2

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.517[a]	.267	.256	.547

The second regression model shows a moderate relationship with a correlation value of 0.517 between the predictors and ecological awareness. The model explains 26.7% of the variance, with an adjusted R-square of 0.256; external factors influence the remaining variation. The estimation error of 0.547 indicates relatively controlled prediction deviations within the model.

Table 15. ANOVA[a] of regression analysis 2

Model	Source	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.341	2	7.671	25.658	.000[b]
	Residual	42.152	141	.299		
	Total	57.493	143			

The ANOVA results for ecological awareness confirm a significant model effect with an F-value of 25.658 and a significance level of 0.000. The regression sum of squares contributes substantially to the total variation, accounting for approximately 27% of the explained variance. The remaining variation indicates the presence of other influencing factors outside the model.

Table 16. Coefficients[a] of regression analysis 2

Model	Variable	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
1	Constant	2.294	.222		10.342	.000
	Learning Approach	.650	.106	.514	6.136	.000
	Student Response	.005	.088	.004	.053	.958

The second regression model shows that ecological awareness is also significantly influenced by the learning approach ($F = 25.658$; $p < 0.001$), with the model explaining 26.7% of the variance ($R^2 = 0.267$). The learning approach has a significant positive effect ($\beta = 0.514$; $p < 0.001$), whereas student response again does not show a significant contribution ($p = 0.958$).

Overall, the key findings indicate that: (1) the experiential learning approach produces higher science literacy and ecological awareness than the inquiry approach, and (2) student response does not significantly influence both outcomes.

3.2. Discussion

The results of the study show a consistent difference between experiential learning and inquiry learning approaches in students' science literacy, which aligns with previous findings on the effectiveness of experiential-based learning in improving conceptual understanding of science in elementary school students [16]. The distribution of science literacy categories shows a dominance of the high category in the experiential learning group, indicating that direct learning experiences strengthen students' scientific understanding [17]. These findings support the view that active student engagement in the learning process can deepen the ability to analyze and interpret scientific concepts [18].

The significant difference in the high-category achievement between the two approaches strengthens the evidence that experiential-based learning provides a more optimal impact on science literacy outcomes compared to conventional inquiry learning approaches [19]. Descriptive mean values indicate that experiential learning produces higher achievement in science literacy, ecological awareness, and student responses than inquiry learning, which shows lower variation across all variables. The increase in ecological awareness in the experiential learning group indicates that contextual learning experiences can foster environmental concern more effectively [20]. More positive student responses in the experiential learning group suggest that emotional engagement and hands-on activities contribute to increased learning motivation [21].

The consistent differences across all descriptive variables show that the quality of learning interaction is an important factor in shaping science literacy and students' ecological attitudes [22]. Regression analysis further confirms that the learning approach significantly influences science literacy, supporting the argument that instructional design plays a central role in students' academic achievement [23]. The significance of the regression model strengthens its predictive power in explaining variations in science literacy outcomes [24], while the positive regression coefficient indicates a strong contribution of the experiential learning approach in improving students' understanding of science concepts [25]. The non-significant effect of student responses indicates that students' perceptions of learning do not, in and of themselves, directly determine improvements in science literacy without appropriate instructional support [26].

Similarly, the regression results show that the learning approach significantly affects ecological awareness, highlighting the important role of direct learning experiences in shaping students' environmental attitudes [27]. The statistical significance of the model confirms its explanatory power in capturing variation in ecological awareness [28], while the positive coefficient indicates that experiential learning is more effective in fostering environmental concern than inquiry learning [29]. The absence of a significant effect from student responses reinforces the notion that environmental awareness is more strongly influenced by authentic experiences than by subjective perceptions of the learning process [30].

From a theoretical perspective, these findings strengthen constructivist and experiential learning theories, which emphasize that knowledge is actively constructed through direct experience and reflection. This study extends previous research by demonstrating that experiential learning not only enhances cognitive outcomes, such as science literacy, but also simultaneously develops affective outcomes, such as ecological awareness, within a single integrated framework. Furthermore, the comparative evidence with the inquiry approach provides a clearer positioning of experiential learning as a more holistic approach in elementary science education.

However, this study has several limitations that should be considered. First, the use of a posttest-only design limits the ability to measure students' initial equivalence in greater depth, despite efforts to control group characteristics. Second, the study was conducted in a specific regional context, which may limit the generalizability of the findings to other educational settings. Third, the variables examined were limited to science literacy, ecological awareness, and student responses, without considering other potential influencing factors such as prior knowledge, socio-economic background, or teacher-related variables. These limitations suggest that future research should incorporate more comprehensive designs, broader samples, and additional variables to obtain a more holistic understanding of learning outcomes.

Experiential learning demonstrates superior results compared to inquiry learning in improving students' science literacy and ecological awareness. The differences across variables indicate that direct learning experiences play an important role in strengthening understanding of science concepts, ecological attitudes, and student learning responses. The regression analysis model shows that the learning approach is the main factor influencing improvements in science literacy and ecological awareness, while student responses do not significantly contribute to changes in learning outcomes.

4. CONCLUSION

This study concludes that the environment-based experiential learning approach is more effective than the inquiry approach in enhancing students' science literacy and ecological awareness, highlighting the importance of direct, contextual learning experiences in strengthening both cognitive and environmental competencies. In practice, these findings suggest that teachers should integrate experiential, hands-on, and environment-based activities into IPAS learning, while curriculum developers and policymakers are encouraged to support student-centered, sustainability-oriented instructional designs. However, this study is limited by a posttest-only design, a specific research context, and a limited number of variables, which may affect the generalizability of the findings. Therefore, future research is recommended to adopt more comprehensive designs, involve diverse samples, and explore additional variables and long-term impacts. Overall, this study contributes to the development of elementary science education by emphasizing the role of experiential learning in fostering scientifically literate and environmentally responsible students.

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