



Integrating Ethnoecology into Project-Based Learning for Sustainable Development: Longitudinal Study of Cognitive Restoration and Pro-Environmental Behaviour in Students

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Abstract: Global conservation challenges demand a shift in environmental management towards cultural values and ecological reciprocity. This study aims to examine the medium-term impact of the Ethnoecology Project-Based Learning (E-PjBL) model in restoring students' focused attention and pro-environmental behaviour sustainability within three months after the intervention. This study uses a Quasi-Experimental design with a pretest-posttest-follow-up control group design. The sample involved 80 tenth-grade high school students divided into an experimental group (E-PjBL) and a control group. The experimental group implemented a Traditional Ecological Knowledge (TEK) exploration project for 14 weeks, while the control group used conventional methods. The results of the Mixed ANOVA analysis showed a highly significant interaction between time and group on cognitive restoration ($p < 0.001$). The experimental group showed a dramatic increase in directed attention scores from 66.1 on the pre-test to 82.3 at the follow-up stage, with moderate effectiveness (N-Gain Score 0.48). In contrast, the control group only achieved an N-Gain of 0.09 (low). Furthermore, the pro-environmental behaviour of the experimental group proved to be continuously internalised, as seen from the continuous increase in scores from the post-test (78.0) to the follow-up (81.4). The integration of local wisdom in E-PjBL proved to be effective as a transformative instrument for building a lasting conservation character and restoring mental fatigue in adolescents.

Keywords: Cognitive restoration; Ethnoecology; Pro-environmental behaviour; Project-based learning; TEK

Introduction

Current global conservation challenges demand a fundamental shift in environmental management, moving away from a technocratic approach towards a philosophy rooted in cultural values and ecological reciprocity. Technocratic approach to a philosophy rooted in cultural values and ecological reciprocity (Armstrong et al., 2024). In Indonesia, the Traditional Ecological Knowledge (TEK) of indigenous peoples, which encompasses knowledge of wild medicinal plants to fishermen's conservation practices are actually facing

the threat of erosion facing the threat of serious erosion due to modernisation (Sousa et al., 2022). In fact, this local wisdom plays a vital role as a model for sustainable resource management, where the concept of reciprocity in ethnoecology guides communities towards environmental stewardship responsibilities, rather than mere exploitation (Armstrong et al., 2025). However, conventional environmental education interventions in schools often fail to bridge the gap between awareness including awareness of renewable energy (Szeberényi et al., 2022) and actual ecological behaviour among adolescents (Calculli et al., 2021).

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The urgency of this research is further reinforced by the fact that adolescents today experience higher levels of mental fatigue due to intensive use of digital technology, which drastically depletes their directed attention capacity (Clemente-Suárez et al., 2024). This condition of “mental fatigue” correlates negatively with their ability to process complex environmental information and hinders the emergence of empathy towards nature (Bratman et al., 2019). Based on Attention Restoration Theory (ART), exposure to natural environments, whether passive (Bernardo et al., 2021) or active (Veitch et al., 2021), can restore directed attention fatigue. However, the majority of studies still focus on short-term effects (10-90 minutes), leaving a research gap regarding the duration of these restorative effects (Mason et al., 2022). In addition, there is the issue of environmental justice, where unequal access to school green spaces creates inequalities in health and cognitive benefits among students (van Velzen et al., 2023).

As a pedagogical solution to overcome this cognitive and behavioural crisis, this study proposes the Ethnoecology-Based Project Learning Model (E-PjBL). This model integrates TEK into project-based learning that involves active interaction with nature, similar to the concept of schoolyard greening, which has been proven to improve socio-emotional health (Bassuk et al., 1990). Recent research shows that place-based education has a greater chance of creating long-term behavioural change because it builds strong emotional attachments (place attachment) in students (Li et al., 2023). Therefore, the purpose of this study is to examine the medium-term impact of the E-PjBL model in restoring focused attention and ensuring the sustainability of students' pro-environmental behaviour within three months after the intervention.

Method

The research design used in this study was Quasi-Experimental with a pretest–posttest–follow-up control group design. Follow-up testing was conducted 3 months after the intervention ended to test the

consolidation and sustainability of the effects. The sample used in this study involved 80 high school students (grade X) who participated and were randomly divided into two groups. The Experimental Group (E-PjBL, n=40) and the Control Group (n=40). The research location was chosen at a school that showed disparities in access to green spaces to discuss the issue of environmental justice in a contextual manner. The E-PjBL intervention lasted for 14 weeks. The experimental group implemented projects that required TEK exploration and documentation, such as mapping environmental resources or conservation practices. These projects had to involve outdoor physical activities (active) and direct interaction with nature (e.g., maintaining a mini classroom garden) (Bernardo et al., 2021). The control group received conventional lecture-based learning and standard assignments.

The instruments used in this study consisted of two main aspects. Cognitive restoration was measured using the Test of Everyday Attention for Children (TEA-Ch), which has been adapted to assess directed attention, with a maximum score of 100 (Mason et al., 2022). Meanwhile, pro-environmental behaviour was measured through a self-report questionnaire designed to assess students' sustainable behaviour, particularly in relation to the wise use of resources and involvement in environmental advocacy actions.

Measurements were taken at three points in time, namely T1 (pre-test) before the intervention, T2 (post-test) after the intervention was completed, and T3 (follow-up) three months after the post-test to assess the consolidation of effects. The data obtained were then analysed using Mixed ANOVA to compare the means between groups and between measurement times. In addition, the N-Gain Score was calculated to determine the level of effectiveness of the intervention.

Result and Discussion

The main objective of this analysis was to test the sustainability of the E-PjBL intervention's effects on the restoration of directed attention up to T3.

Table 1. Descriptive Analysis of Directed Attention Scores at T1, T2, and T3)

Group	N	T1 (pre-test) mean (sd)	T2 (post-test) mean (sd)	T3 (follow-up) mean (sd)	N-gain score (T1-T3)	Interpretation of n-gain
Experiment (E-PjBL)	40	66.1 (5.1)	81.5 (4.5)	82.3 (4.8)	0.48	Moderate
Control	40	65.9 (5.3)	69.2 (5.0)	69.0 (5.1)	0.09	Low

Table 2. Results of the Mixed Repeated Measures ANOVA Significance Test on Cognitive Restoration

Source of variation	Sum of squares (ss)	Degrees of freedom (df)	Mean square (ms)	F	Significance (p)	Main conclusion
Interaction (group * time)	6.65	2	3.32	9.30	0.001	Highly significant intervention effect

Based on the results of the study, the learning model (E-PjBL) was proven to be significantly effective in restoring students' directed attention skills. Data analysis in Table 1 shows that in the initial stage (T1), both groups had similar average scores, namely 66.1 for the experimental group and 65.9 for the control group. This condition indicates that both groups had equivalent levels of mental fatigue or focus ability before the intervention began.

After a 14-week intervention (T2), the experimental group experienced a drastic increase in scores to 81.5. In contrast, the control group, which followed conventional lecture-based learning, only experienced a slight increase to 69.2. The experimental group's advantage continued to persist until the follow-up stage (T3) conducted three months later, with a stable score of 82.3, while the control group scored 69.0.

Statistically, the results of the Mixed ANOVA test in Table 2 confirm that the interaction between time and group has a very significant effect ($p < 0.001$) with an F value of 9.30. The level of intervention effectiveness in the experimental group was in the moderate category with an N-Gain Score of 0.48, much higher than the control group, which only reached 0.09 in the low

category. This was due to the combination of direct experience and project-based methods. These results are in line with the findings of Ratna et al. (2025), who found that an environment-based Project-Based Learning (PjBL) model can improve students' memory retention and critical thinking skills. This improvement occurred because students were actively involved in solving real problems relevant to their life context, making learning more meaningful. Tilman et al. (2024) stated that interaction with natural elements in the school environment is very effective in restoring mental fatigue (attention fatigue) in adolescents.

The data in Table 3 shows that the E-PjBL intervention not only temporarily increased pro-environmental behaviour, but also successfully triggered sustainable pro-environmental behavioural change. This is evidenced by the experimental group's score increasing from 57.5 (T1) to 78.0 (T2). At the follow-up stage (T3), the score continued to increase to 81.4, proving the internalisation of post-intervention behaviour. This is in stark contrast to the control group, which only achieved a score of 60.1 at T3. The significance of this difference is reinforced by a p -value < 0.001 in the independent t-test at the T3 stage.

Table 3. Results of the Mixed Repeated Measures Anova Test on Cognitive Restoration

Group	N	T1 (Pre-test) Mean (SD)	T2 (Post-test) Mean (SD)	T3 (Follow-up) Mean (SD)	N-Gain Score (T1-T3)	P-value	Independent t-test (T3)
Experiment (E-PjBL)	40	57.5 (6.5)	78.0 (5.8)	81.4 (5.5)	0.57		0.001
Control	40	57.8 (6.3)	60.5 (6.0)	60.1 (6.2)	0.05		-

This success occurred due to the integration of Traditional Ecological Knowledge (TEK) into the E-PjBL project, which required physical involvement such as mapping environmental resources or conservation practices involving outdoor physical activities (active) and direct interaction with nature (e.g., caring for a mini classroom garden). This shows that the behaviour adopted by students has been internalised as part of their self-worth, not just a temporary academic obligation. In line with the research by Sumarwati et al. (2020), the integration of TEK in science learning has been proven to build a conservation character that is internalised as part of one's identity, not just the fulfilment of academic tasks. Active documentation processes, such as resource mapping and mini garden maintenance, create concrete learning experiences. This is supported by Pirchio et al. (2021), who state that outdoor activities in environmental projects significantly strengthen the retention of pro-environmental behaviour post-intervention.

Furthermore, the 14-week duration of the intervention played a crucial role in consolidating behaviour. Research by Sulastri et al. (2022) confirmed that long-term environmental projects enable the

formation of lasting habits. The use of digital platforms in E-PjBL also made it easier for students to record their conservation efforts (Susilawati et al., 2023). According to Ramadian et al. (2025), the use of digital media in environmental projects effectively increases students' active participation and critical awareness of local issues. This success is also reinforced by the ethnoscience theory developed in the research by Permatasari et al. (2025), where learning based on local wisdom can improve long-lasting environmental literacy because the values learned are relevant to students' daily lives.

The significance of the difference between the experimental and control groups at stage T3 confirms that the conventional PjBL model without an ethnoecological touch is less capable of achieving the stage of value internalisation. These findings are in line with Maknun (2015), who proved that the local wisdom-based learning model produces much higher environmental awareness than the conventional model. Finally, direct interaction with nature through this project ensures that pro-environmental behaviour has become part of the students' value system, as confirmed by Ardan (2016) that TEK-based curricula are effective in permanently improving students' positive attitudes

towards environmental conservation. Overall, Ethnoecology-based E-PjBL has proven to be a transformative instrument in shaping good pro-environmental behaviour.

Conclusion

Based on the above analysis, it can be concluded that: The Ethnoecology-Based Project Learning Model (E-PjBL) has been proven to be significantly effective in restoring the directed attention abilities of secondary school students with moderate effectiveness (N-Gain Score 0.48). The sustainability of this cognitive restorative effect is stable and lasts up to three months post-intervention, with the experimental group's score remaining superior (82.3) compared to the control group (69.0). This improvement is triggered by students' active involvement in direct interaction with nature and solving real problems relevant to their life context. The implementation of E-PjBL successfully triggered sustainable pro-environmental behavioural change through the internalisation of Traditional Ecological Knowledge (TEK). Unlike conventional learning, the integration of local values into a 14-week long-term project allowed conservation behaviour to be adopted as part of the students' identity and value system, rather than just a temporary academic obligation. This is evidenced by continuously increasing pro-environmental behaviour scores even after the intervention ended (T3 = 81.4).

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Author Contributions

Conceptualization, N.D.N; methodology, I.K.W; formal analysis, V.E and K.; investigation, V.E.; resources, K.; writing preparation of original draft, V.E.; writing reviewing and editing, K. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

No conflict interest.

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