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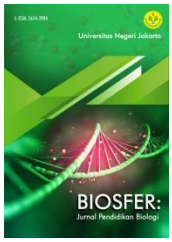

Ethno-PjBL: A pedagogical strategy to foster students' critical thinking skills on environmental science topics

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ABSTRACT

Ineffective teaching is one of the factors influencing the low level of students' critical thinking skills. Rooted in local wisdom, ethno-PjBL integrates project-based learning principles with ethnopedagogical values, requiring students to think critically. This research aims to determine the impact of the ethno-PjBL on students' critical thinking skills in addressing real-life environmental issues. This research uses a quasi-experimental method and a pretest-posttest non-equivalent control group design. Up to 100 of the 353 tenth-grade students at one of the upper secondary schools in Banda Aceh were selected using purposive sampling techniques. This research used 17 multiple choices with written justification tests, developed based on Ennis's critical thinking indicators. An independent sample t-test was used to assess the intervention effect and n-gain was used to measure the score improvement. Data were analyzed using an independent sample t-test to assess the intervention effect and n-gain to calculate score improvement. The findings prove a significant effect (0.010 < 0.05) and a higher n-gain in the experimental group (0.46) compared with the control group (0.25), indicating that the ethno-PjBL effectively fosters students' critical thinking skills. Integrating indigenous knowledge in project-based learning should be encouraged to nurture students' critical thinking skills.

INTRODUCTION

One of the important skills needed by 21st-century students is critical thinking (Aizikovitsh-Udi & Cheng, 2015; Facione, 2011; Hasanah et al., 2023; Kalelioğlu & Gülbahar, 2014). Due to its significance, the Learning Metrics Task Force (2013) has included critical thinking skills in the sub-domain of the Global Framework of Learning Domains (the framework for 21st-century skills constructed by UNESCO). Similarly, Indonesian educational institutions also emphasize on developing students' critical thinking skills (Weruin, 2022). The learning process that develops critical thinking skills includes effective learning (Chukwuyenum, 2013). In addition, critical thinking improves academic achievement (Anazifa, 2016; Mohamed & Mohammed, 2016; Wicaksono, 2014) and deepens interdisciplinary understanding (Zandvakili et al., 2019). Due to the need for critical thinking skills in all aspects of life, these skills become an intellectual asset for every individual (Fitriani et al., 2022).

Despite its importance, previous research conducted in Indonesia, particularly in Aceh, has consistently shown that students lack critical thinking skills. There are several studies that have highlighted this problem, indicating deficiencies in aspects of analyzing, making or drawing conclusions, interpreting, giving and answering questions, making assumptions, reasoning, providing solutions to problems, and the capacity to convey clear explanations (Hidayati, 2016; Saputri et al., 2018; Muhibbuddin et al., 2020; Ramdani et al., 2021; Elfrida et al., 2023). As stated in various studies, some causes contributing to the problem are an over-reliance on memorization (Jamaluddin et al., 2023), insufficient supporting media and innovative learning (Rahman et al., 2021), and the lack of attention of students' socio-cultural environment (Wati et al., 2021) where science learning should provide opportunities for students to develop scientific attitude and local culture to provide greatest benefits (Suastra, 2010).

The importance of developing students' critical thinking skills is also a target of the Merdeka curriculum (Ghassani et al., 2023; Iskandar et al., 2023) , which is required to be implemented through: 1) project-based learning activities to develop soft skills and characters by *Profil Pelajar Pancasila*; 2) differentiated learning according to students' abilities and adapting to local context and content (Sari et al., 2023). One of the innovative learning approaches that is in line with the demands of the Merdeka curriculum and can be a solution for developing students' critical thinking skills is integrating an ethnopedagogical approach through project-based learning (PjBL). Ethnopedagogical learning through PjBL ultimately improves critical thinking skills (Hanum et al., 2023; Rahmawati et al., 2019).

Ethno-pedagogy offers a strong connection between scientific principles and cultural contexts, thus ensuring a more meaningful and contextually grounded learning process (Sugara & Sugito, 2022; Supriyadi et al., 2019) , which has been proven that contextual learning successfully remedies flaws in critical thinking (Fitriani et al., 2020). Cultural elements also affect the motivational and affective components of self-regulated learning (Sappor, 2022) , which is necessary for the maximum development of students' critical thinking skills (Lidiawati et al., 2022). This study implements ethno-pedagogy through the RTSRE design. The design, which incorporates review, task, solution, reflection, and evaluation, can be defined as a scientific learning design based on local knowledge (Subali et al., 2015). Further, there is much evidence that the implementation of PjBL significantly enhances the development of critical thinking skills during the learning process (Buroidah et al., 2023; Issa & Khataibeh, 2021; Chiu, 2020). According to Efliana et al. (2022) the syntax of PjBL consists of starting with essential questions, designing a plan for the project, creating a schedule, monitoring the students and the progress of the project, assessing the outcome, and evaluating the experience.

A variety of studies have explored the combination of ethno-pedagogy and PjBL in enhancing Indonesian students' critical thinking skills, such as the integration of ethno-pedagogy on wastewater treatment projects (Rahmawati et al., 2019), on solar system topics (Rahmawati et al., 2020), in mathematics learning (Susanto et al., 2021), in learning media (Niman & Wejang, 2022), in chemistry learning (Hanum et al., 2023), "*Dangke*" in science education (Haliq et al., 2023), "Kudus" (Hikmawati et al., 2023). In contrast to previous research, this study not only focuses on the impact of ethno-pedagogy through PjBL but also investigates whether students' critical thinking skills outcomes differ between two student-centered models: project-based learning and problem-based learning. In addition, research on integrating ethno-pedagogy and PjBL and its impact on students' critical thinking skills in the context of Biology learning on environmental science topic, which becomes more vital to both global education systems and sustainability initiatives, especially in Aceh, is still limited. This is in line with previous

research that the frequency of ethno science studies in Aceh is low compared to other regions in Indonesia (Kasi et al., 2021).

The ethno-pedagogy referred to in this research involves using local wisdom practices (Acehnese culture) as an effort to overcome or preserve the environment and mitigate environmental changes that occur, which are used as a medium for studying environmental changes and preservation topics. The results of this research will provide an overview for teachers, students, and education staff about the impact of combined learning on ethno-pedagogy and project-based learning on students' critical thinking skills in lessons related to the environment.

METHODS

Research Design

This research used a Quasi-experimental method (Shadish & Luellen, 2005), in which the experimental group was given treatment using an ethnopedagogical approach through project-based learning, while the control group used an ethnopedagogical approach through problem-based learning. The design used is a Pretest-posttest Non-equivalent Control Group design, which provides a pre-test before being treated and a post-test after being given treatment in each group to measure the consequences of the treatment (Shadish & Luellen, 2005).

Population and Samples

This research was conducted at one of the upper secondary schools in Banda Aceh in the 2023/2024 academic year. Up to 100 of the 353 tenth-grade students were selected using purposive sampling techniques based on students' similar average Biology scores from the previous semester (Table 1). This sampling method was used to assure that the students selected had similar academic performance so as to reduce any pre-existing discrepancies pertaining to content knowledge that could interfere with the instructional intervention. As mentioned by Etikan et al. (2016) that purposive sampling aims to focus on individuals with specific traits who will be more qualified to contribute to the pertinent research.

Table 1
The Research Samples

Groups		Number of students	Biology average score
Experiment	X-1	24	88
	X-3	31	89
Control	X-2	27	88
	X-4	18	89

Instrument

The instrument of critical thinking test was developed based on Ennis' indicators (Ennis, 1985; Ennis, 2016) (Table 2). Ennis (1985) offers a simple model comprising dispositions and abilities classified into five broad categories: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. Ennis (2016) expands this structure by situating the indicators in curriculum planning and teaching practice areas, with specific examples and detailed exemplars. This study integrates aspects of both sources by using the major categories identified in 1985 as basic structure of the test instrument developed and using the practical adaptations and contextual examples in 2016 as a reference for developing test instruments. The type of test instrument is multiple choice with written justification. Several tests were used to check the quality of the instruments. Firstly, the data of theoretical validity by 3 experts were analyzed using V Aiken (Azwar, 2014). Secondly, empirical validity was carried out on a small scale, and its data were analyzed using the program of SPSS Statistics 23 (validity, reliability, item analysis (the index of difficulty and the differentiation test).

Table 2
Critical Thinking Skills Indicators

Aspects of critical thinking skills	Sub-aspects	The Biology Context of Environmental Topics
Elementary clarification	Focusing on a question	1. Presented with several types of local household waste, students group the types of waste into certain types of waste as mentioned in the question.

Aspects of critical thinking skills	Sub-aspects	The Biology Context of Environmental Topics
		2. Presented with several local environmental conservation practices, students evaluate the types of conservation practices that aim to prevent land pollution.
	Analyzing arguments	1. Presented with data from research on waste management, students determine the types of environmental conservation management program actions presented in the discourse.
		2. Presented with an article related to environmental changes occurring around them, students identify reasons not mentioned in the article related to incidents in the article.
	Asking and answering questions or clarification and or challenge	1. Given a discourse, students identify local practices of one of the 9 R programs in minimizing solid waste in the answer choices given.
Basic support	Judging the credibility of a source	1. Students assess the reputation of the source and content of the answer choices given regarding the negative effects of air pollution on human health.
	Observing and judging observation reports	1. Students predict the possible types of waste that can reduce soil quality through student involvement in the observation process presented.
Inference	Deducing and judging the deductions	1. Students interpret statements from the information presented regarding the accumulation of pollutants in the food chain.
	Inducing and judging inductions	1. Students make assumptions based on data or information presented regarding pollution.
		2. Students choose the right hypothesis or assumption from statements related to noise pollution.
	Making and judging value judgments	1. Students consider one of alternatives referring to local practices to address the problems presented regarding preservation.
		2. Students consider one of alternative decisions referring to cases of pollution on earth.
Advanced clarification	Defining terms and judging definitions	1. Students define terms supported by the text in the article presented.
	Identifying assumptions	1. Students predict possible causes supported by information in the article related to pollution cases on earth.
Strategy and tactics	Deciding on an action	1. Students make decisions regarding actions to handle certain types of waste.
	Interacting with others	1. Students plan logical and effective strategies to avoid predictions of greater impacts in the future that are supported by information and data in the discourse.

The result of theoretical validity showed that only 32 items were valid out of the 36 items provided. Then, the 32 items were tested for empirical validity. The result showed that only 17 items are valid out of 32 items, which was measured using Pearson correlation. The reliability index or the value of r_{11} using K–R 20 is 0.843, which is higher than the r_{table} (0.843 ≥ 0.334); the critical thinking test is reliable. Based on the calculation of the difficulty index and the differentiation test, the 17 items had been confirmed to be used in this research.

Procedure

The present study was conducted on environmental science topics. The procedures are explained as follows: managing permits to conduct research in schools; preparing learning tools in the form of syllabi, lesson plans, student worksheets, etc.; created an instrument to measure students' critical thinking skills; collecting the data. The stages of implementation in collecting data consist of: a pre-test of the test instrument was provided before the intervention in both the experimental and control groups; interventions were provided in the experimental and control groups according to learning tools

that had been validated by three experts over three meetings; student activities during the intervention were observed by the researchers with the assistance of observer (biology teacher); A post-test of the test instrument was provided after the intervention in both the experimental and control groups. Last, the collected data were processed, and conclusions were drawn.

Data Analysis Techniques

An independent sample t-test was used to find out whether there is a significant influence of ethno-PjBL on students' critical thinking skills. This hypothesis testing (t-test) was done after the prerequisite tests (normality and homogeneity tests) were carried out. In addition, the normalized gain (n-gain) test was used to find out the improvement of students' critical thinking skills using the n-gain formula (Meltzer, 2002; Hake, 1999).

RESULTS AND DISCUSSION

The results of statistical tests, the normality, homogeneity, and hypothesis tests, of students' critical thinking skills, which were analyzed using SPSS Statistics 23, are presented in Table 3.

Table 3
Influence Analysis

Group	Normality test		Homogeneity Test*** (Sig.)	t test****	
	Pre-test (Sig.)	Post-test (Sig.)		t value	Sig. (2-tailed)
Experiment	.083*	.076*	.996	2.625	.010
Control	.087**	.125**			

* *Kolmogorov-Smirnov, sig > 0.05*
** *Shapiro-Wilk, sig > 0.05*
*** *Levene, sig > 0.05*
**** *Independent sample t-test, sig < 0.05*

Table 3 highlights the significant influence of the Ethno-PjBL on students' critical thinking skills. This result is influenced by the PjBL, which offers a more effective way for students to engage deeply in the learning process, encompassing investigation, exploration, and reflection over a longer timeframe than a control group using problem-based learning (PBL). Issa and Khataibeh (2021) explained that investigation and exploration in PjBL can encourage or stimulate individuals to think more critically and Watson and Glaser (2012) stated that an investigative attitude is an important aspect in developing critical thinking skills. The generous timeline provided by PjBL allows ample opportunity for iterative thinking, problem refinement, and reflection, important aspects in developing critical thinking. As mentioned by Anazifa & Djukri, (2017) problem-based learning will be as effective as PjBL if used in long-term learning. In addition, PjBL provides a scaffold for higher-order thinking through realistic and complex problem-solving activities. Such complexity in projects promotes the use of advanced cognitive strategies according to Barron et al. (1998, in Stefanou et al., 2013).

The traditional knowledge integrated into PjBL adds complexity and a unique depth to the learning process, where students are not only challenged to evaluate local environmental practices but also to adapt and assess them about modern environmental issues. For instance, in a sustainable waste management project, students explore Acehnese practices in creative and sustainable waste management and analyze those practices in minimizing the amount of single-use plastic products and increasing the number of recycled products by comparing them to modern lifestyles. This process (analyze, evaluate, and understand the broader implications of environmental information) not only improves their understanding but also their critical thinking skills. Scriven and Paul (1987) and Ennis, 2016) stated that when individuals actively and skillfully conceptualize and apply, analyze, synthesize, and evaluate information collected from observations, experiences, reflections, reasoning, or communication, as a guide for individuals to believe information and take action, then individuals have trained their critical thinking skills. In addition, Traditional information systems contain core practices that can be adapted to face modern challenges. This aligns with the view of Boafo et al. (2016) Supriatna (2016), who argue that traditional ecological knowledge can serve as a valuable foundation for sustainable environmental education.

Based on empirical evidence during this study, there are several key differences were observed between the experimental and control groups, underscoring the impact of two different pedagogical strategies.

Student Involvement and Responsibility

In the PjBL group, all students actively participated and held clear roles in their group projects, promoting equal engagement in the learning process. This contrasts with the control group, where only some students were consistently involved, which can be assumed that only a few students were actively involved in understanding information and developing critical opinions. As Cassum and Gul (2016) noted, higher student activity supports the development of critical thinking skills.

Depth of Exploration

Students in the experimental group engaged in deeper problem analysis and were able to examine issues from multiple perspectives, facilitated by the longer period of PjBL activities, so that they can continue to refine their understanding through investigations, which ultimately encouraged students to think critically during the process. In contrast, the control group tended to provide surface-level responses due to time constraints. This empirical evidence can be seen during the presentation and from the answers of students' worksheets. This has been confirmed by Issa and Khataibeh (2021) that investigation and exploration in PjBL can encourage or stimulate individuals to think more critically.

Autonomy in the Learning Process

The PjBL syntax, in the experimental group, gives students more autonomy, which allows for greater encouragement of critical thinking practice compared to PBL (the control intervention). Through PjBL, students have the freedom to determine the goals of the type of project, make decisions about the direction of the project, and be responsible for the learning process. This autonomy empowers students to control their learning process, which leads to the encouragement of critical thinking, especially when students take ownership in the process of resolving obstacles that arise during the project completion process. Buroidah et al. (2023) and Issa and Khataibeh (2021) explained that PjBL improves critical thinking skills through the processes of completing projects.

Students' Creativity in Projects

The open-ended nature of projects in the experimental group allowed students to be creative in designing, testing, and refining their outputs. These processes naturally stimulated critical thinking as students navigated obstacles and revised their solutions. Research Witarsa and Muhammad (2023) supports this link between project-based tasks and the development of critical thinking through discussions and decision-making processes to find solutions to problems.

Students' Enthusiasm

The presence of ethno-pedagogy as an approach in the PjBL learning process increasingly promotes the improvement of students' critical thinking skills by making problems more contextual and relevant to the students' environment. This is supported by Wirawan et al. (2021) that the use of local wisdom contexts stimulates students' critical thinking skills because local wisdom offers a contextual learning process, and Wlodkowvski (2008, in Carvalho et al., 2015) that teaching emphasizes learning activities which represent problems faced in everyday life, greatly supports the improvement of students' critical thinking skills.

On one hand, students in the experimental group (using PjBL syntax) had the opportunity to explore culturally relevant topics and issues in the context of their projects. This relevance can increase students' enthusiasm for the project by connecting learning to culturally relevant content and issues (the context that can be linked to the cultural experiences in the students' environment). Enthusiasm drives curiosity and a desire to explore concepts further, as mentioned by Vogelaar et al. (2025) that curiosity is a component of enthusiasm that reflects an active interest and desire to explore or learn, supporting the broader goal-conducive nature of enthusiasm. Additionally, Sobel and Letourneau (2018) this curiosity encourages the potential for exploring knowledge and is the most powerful motivator towards learning. This exploration process is important for critical thinking (Issa &

Khataibeh, 2021) because it involves analyzing and evaluating information from multiple perspectives to reach a logical conclusion.

On the other hand, in students in the control group, although the problems presented were as relevant as those in the experimental group (increasing students' enthusiasm), the strong urge to engage in learning was limited by the learning period so students only looked for answers to problems without delving into the intricacies (only give simple answers) (apparent from the presentation and students' worksheets). A short learning period puts more pressure on students to complete assignments and produce results within a tight time frame. This pressure has a negative impact on students' enthusiasm for learning, resulting in reduced enthusiasm. Chen and Tu (2021) strengthen this empirical evidence by their research that when students feel nervous, anxious or stressed, their learning motivation can be low. In line with Chen and Tu (2021), Johnsen et al. (2017) also found that pressure is negatively correlated with learning motivation, meaning that the greater the pressure, the lower their learning motivation.

The improvement of students' critical thinking skills in the experimental and control groups can be seen in Tables 4 and 5.

Table 4
The Results of the N-gain Test on Students' Critical Thinking Skills

Group	Average		N-gain	Criteria
	Pre-test	Post-test		
Experiment	24.28	50.91	0.46	Medium
Control	24.97	41.44	0.25	Low

Table 5
The Results of the N-gain Test for Each Critical Thinking Indicator of the Experimental Group

Indicators	Average		N-gain	Criteria
	Pre-test	Post-test		
Elementary clarification	22.12	46.67	0.31	Medium
Basic support	10.91	41.82	0.32	Medium
Inference	29.45	48.36	0.32	Medium
Advanced clarification	26.36	53.64	0.33	Medium
Strategy and tactics	29.09	76.36	0.71	High

The data in Tables 4 and 5 show an increase in students' critical thinking skills in the experimental and control groups. However, the improvement in the experimental group is higher than in the control group. Referring to the criteria proposed by Hake (1999), the experimental group is included in the medium category, while the control group is included in the low category. The findings of the n-gain test make it clearer that the ethno-PjBL is more effective in improving students' critical thinking skills than the ethno-pedagogy through PBL. Moreover, n-gain analysis also revealed that the effectiveness of the intervention varied across the five Ennis indicators of critical thinking skills.

The increase in strategy and tactics indicator is higher than other indicators because the process of solving complex problems through projects directly improves students' ability to develop strategies and reflection processes continuously to monitor project progress and make adjustments during the projects, which strengthens students' tactical thinking. This is in line with Isro et al. (2021) that the indicator of strategy and tactics has a better score than other indicators after the implementation of project-based learning, which is influenced by the collaboration process in creating projects to find solutions. This collaboration trains students to be able to determine good actions in solving problems. Grossman et al. (2022) highlighted that PjBL requires students to engage in ongoing investigation (involving cycles of planning, acting, and reflecting), which requires continuous adjustment and refinement of strategies based on ongoing feedback and reflection. This process inherently develops the learner's ability to think strategically and tactically because they have to plan, monitor, and adjust their approach to complete their projects. In contrast, elementary clarification and basic support are less involved in this iterative process because they do not require the same level of planning, monitoring, and adjusting. Both indicators are more about understanding and remembering information, which would be better supported through structured and hands-on teaching where clear, concise explanations and step-by-step guidance can be provided.

Inference and advanced clarification indicators involve drawing conclusions, identifying assumptions, and defining terms from available evidence or data, but based on the empirical data, many students provided their answers not specifically referring to the available data. In other words, many students provided their answers with general explanations. Fitriani et al. (2019) stated that the increase in inference is lower than the strategy and tactics, which can be caused by drawing conclusions that do not focus on the specific data provided (students are only able to draw general conclusions). Isro et al. (2021) Also explained that the increase in advanced clarification is in the moderate category (lower than the strategy and tactics) because many students use memorization to answer questions without connecting concepts to the situation that they are facing. Finally, in general, a meta-analysis study Abrami et al. (2008) regarding the effectiveness of teaching critical thinking found that certain teaching strategies are more effective for certain critical thinking skills than other teaching strategies, which means that certain teaching approaches or strategies are more suitable for developing certain aspects of critical thinking.

CONCLUSION

This study explored one of the innovative pedagogical strategies that is in line with the demands of the Merdeka curriculum and can be a solution for developing students' critical thinking skills, which is ethno-project-based learning/ethno-PjBL in the context of environmental changes and preservation topics. The findings of this study revealed that there is a significant influence of ethno-PjBL on students' critical thinking skills. Integrating of the PjBL model with local wisdom engages students in-depth with environmental concerns, addressing real-world problems, critically evaluating traditional ecological practice knowledge, and applying those practices to modern challenges. In addition, traditional information systems contain core practices that can be adapted to face modern challenges; thus, taking part in environmental projects that incorporate local wisdom elements aids students in developing practical solutions to environmental problems and builds confidence or awareness towards environmental conservation, which ultimately influences the development of students' critical thinking. As opposed to the use of the PBL model in the control group, PjBL affords a longer and more immersive learning experience that emphasizes critical analysis, reflection, and solution-oriented thinking. Ethno-PjBL can be a significant reference for educators and researchers to support students' cognitive development through innovative, culturally relevant means. Finally, these findings indicate the need for future biology instruction to transform into more context and culture-based strategies to learning. With the interweaving of ethnopedagogical values within scientific inquiry, this pedagogical strategy makes it easier for traditional ecological knowledge to meet modern science in creating meaningful and relevant learning experiences for students.

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