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The Effect of Ethnoscience-Based Problem-Based Learning on Students' Critical Thinking Ability: A Study on Buffer Solution Material

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ABSTRACT

Students' low critical thinking skills on buffer solutions remain a challenge in chemistry education, and the application of an ethnoscience approach to address this topic has not been extensively researched. This study aims to determine the effect of the ethnoscience-based Problem-Based Learning (PBL) model on students' critical thinking abilities. This quasi-experimental research uses a pretest-posttest control group design. The population in this study was all 95 students of MA Syaikh Zainuddin NW Anjani. The sample included 25 students from class XI MIPA A as the control class and 24 students from class XI MIPA B as the experimental class. The sample was selected using purposive sampling. The data collection technique in this study was an essay test. The Research data were analyzed using normality and homogeneity tests as prerequisites, then continued with an independent-samples t-test using SPSS software. The results showed that the significance value of the hypothesis test using the Independent-Samples t-test was less than 0.05. This indicates that the ethnoscience-based problem-based learning model significantly affects students' critical thinking abilities.

Keywords: problem-based learning, ethnoscience, critical thinking ability, buffer solution

INTRODUCTION

Education plays a crucial role in shaping human resources capable of facing 21st-century challenges by developing essential competencies. One such competency that science education must foster is critical thinking, as it enables learners to analyze, evaluate, and solve problems scientifically.

Science is one of the fields of study students study in school. Imkari et al [1] stated that science education is a vehicle for students to learn about the natural environment and the prospects for further development in its application in everyday life. In line with this, Panggabean et al. [2] stated that through science learning, students can understand various concepts and natural phenomena through scientific processes that involve investigation, observation, and the development of ideas. Based on the results of research conducted by [3], which stated that Indonesia's achievements in the results of The Programme for International Student Assessment (PISA) in 2018, which is conducted every 3 years on 600,000 students aged 15 years, showed that in the field of science ability, Indonesia was ranked 71st with an average score of 396 out of 79 PISA participating countries. This shows that Indonesia's science literacy performance remains far below the international average, ranking among the lowest-performing participating countries.

Chemistry is one of the science subjects taught in high school. In practice, chemistry instruction should facilitate students' development of critical, logical, and systematic thinking patterns, as well as higher-order thinking skills. One higher-order thinking ability teachers need to develop when managing chemistry learning in the classroom is critical thinking. Critical thinking is the ability to analyze, evaluate, and make decisions logically and rationally using collected data and information [4]. Yudha et al. [5] state that an individual with critical thinking skills can identify important issues, formulate questions clearly, and define problems systematically as a basis for finding solutions. This indicates that students need to develop logical and rational thinking skills to understand a concept and find solutions to the problems they face.

Initial observations at MA Syaikh Zainuddin NW Anjani show that students' critical thinking ability regarding Chemistry concepts, especially buffer solutions, remains relatively low. This is evident in students' learning outcomes when working on HOTS questions. Several factors cause the problems that occur: the learning process remains teacher-centered; teachers insufficiently involve students in the learning process; students are rarely trained to solve problems; and teachers rarely relate science material to students' daily lives. This affects student learning outcomes and makes learning less meaningful. In addition, students' low critical-thinking ability stems from science education that does not consider students' socio-cultural environment. In fact, local wisdom values can be used in science learning in schools/madrasas, especially chemistry, so learning becomes more meaningful. Emda [6] views the learning process as becoming more meaningful when science concepts are linked to community activities that reflect the culture and local wisdom of the students' surroundings. Furthermore, contextual learning that integrates everyday phenomena and local wisdom has been shown to enhance student engagement, strengthen understanding of chemical concepts, and develop critical thinking ability, as students learn through experience [7]. Rosyidah et al. [8] state that local wisdom helps make scientific concepts contextual, meaningful, and culturally relevant for students.

Therefore, one effort to provide deeper meaning in the learning process is to combine culture with science, commonly known as ethnoscience. Halimah et al [9] stated that ethnoscience learning is an educational innovation that combines cultural wisdom with scientific principles. This ethnoscience approach focuses on cultural aspects and local wisdom, providing deeper meaning in the learning process. Ethnoscience-based learning can also enhance student engagement, strengthen conceptual understanding, and develop critical thinking skills, as students confront contextual problems relevant to their lives [10].

The ethnoscience approach can be combined with a learning model that can link science concepts, especially chemistry, with community activities around students, namely the Problem-Based Learning (PBL) model. A meta-analysis [11] indicates that the problem-based learning model is the most effective when combined with an ethnoscience approach in chemistry instruction, compared with several other models. The PBL model aligns with the constructivist principle that students actively construct the concepts being taught and can apply them in their daily lives [12]. According to Fitri et al., the Problem-Based Learning (PBL) model is an instructional approach that utilizes real-life problems for students to solve, thereby enhancing their critical thinking, reasoning, and problem-solving skills [13]. In line with this, Handika and Wangid stated that PBL is a learning model that emphasizes problem-solving as the starting point for the learning process [14]. If implemented in schools, this PBL model has shown strong success in improving learning outcomes and developing students' thinking ability [15]. Research findings by Putri et al. indicate that implementing an ethnoscience-integrated problem-based learning model influences students' critical thinking ability on the topic of ecosystems [16]. Research by Yulianto et al. stated that the ethnoscience-based Problem-Based Learning (PBL) model influences the learning outcomes of grade 4 students in cluster 5 of Jatibanteng sub-district in science subjects [17]. Using the PBL learning model in science learning affects the critical thinking and communication skills of prospective PIAUD IAIQH Bagu teachers [18]. In addition, including ethnoscience elements in PBL can increase the relevance of learning to the surrounding environment while optimizing the effectiveness of science teaching [19]. Unlike previous studies that focused on elementary science, creative thinking skills, or general learning outcomes, this study specifically examines the effect on critical thinking ability in the context of buffer solution material at the senior high school level, an area that remains underexplored.

Therefore, this study aims to determine the effect of the Ethnoscience-Based Problem-Based Learning model on students' critical thinking ability at MA Syaikh Zainuddin NW Anjani, particularly in buffer solution material.

RESEARCH METHODS

This research is a quantitative study with a quasi-experimental design. The research design used in this study is a pretest-posttest control group design. Table 1 below shows the model.

Table 1. Pretest Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	Y	O_4

X represents the treatment using the ethnoscience-based Problem-Based Learning model, while Y represents conventional learning treatment applied to the control class.

The population in this study was all 95 students of MA Syaikh Zainuddin NW Anjani. The sample included 25 students from class XI MIPA A as the control class and 24 students from class XI MIPA B as the experimental class. The sample was determined using a purposive sampling technique. Because these two classes had the lowest average learning outcomes compared with the other grade XI classes, they were selected as the research subjects. Data on students' critical thinking ability were obtained from tests. The instrument used to measure students' critical thinking ability consisted of an essay test comprising five items, developed based on five critical thinking indicators: 1) providing simple explanations, 2) building basic skills, 3) concluding, 4) providing further explanations, and 5) setting strategies and tactics. Two validators reviewed the instrument, and its reliability was tested using Cronbach's alpha, yielding 0.821. This aligns with Silaban et al., who stated that a Cronbach's alpha range of $0.6 \leq \alpha < 0.8$ falls into the 'high' category [20]. This indicates a high level of reliability, making the instrument suitable for use in data collection. The Research data were analyzed using normality and homogeneity tests as prerequisites, followed by an independent-samples t-test using SPSS.

The stages of the PBL model used in this study consist of five steps: 1) orienting students to the problem, 2) organizing students for learning, 3) guiding individual and group investigations, 4) developing and presenting problem-solving results, and 5) reflecting on or evaluating the problem-solving process [21].

RESULT AND DISCUSSION

Based on the research conducted, Table 2 presents the pretest and posttest data on students' critical thinking ability in the experimental and control classes 2.

Table 2. Pretest-Posttest Data on Students' Critical Thinking Ability

Data	Pretest		Posttest	
	XI MIPA A (control)	XI MIPA B (Experiment)	XI MIPA A (control)	XI MIPA B (Experiment)
Maximum Score	75	70	90	100
Minimum Score	25	25	55	60
Average	52.8	50.0	73.8	86.7

Based on Table 2, the mean pretest and posttest scores differ between the two groups. The pretest assessed students' initial proficiency in each group and served as the basis for designating the experimental group. Analysis results indicate that the mean pretest score for class XI MIPA A was higher than that of class XI MIPA B. Consequently, class XI MIPA B was selected as the experimental group due to its relatively lower initial proficiency, thereby allowing for a more objective assessment of the impact of the ethnoscience-based PBL model. Meanwhile, the posttest was administered following the intervention (the ethnoscience-based PBL model); the results show an increase in mean scores for both groups compared to the pretest, indicating a change in student proficiency after participating in the learning process using the ethnoscience-based PBL model. Figure 1 presents data on students' critical thinking ability from the post-test.

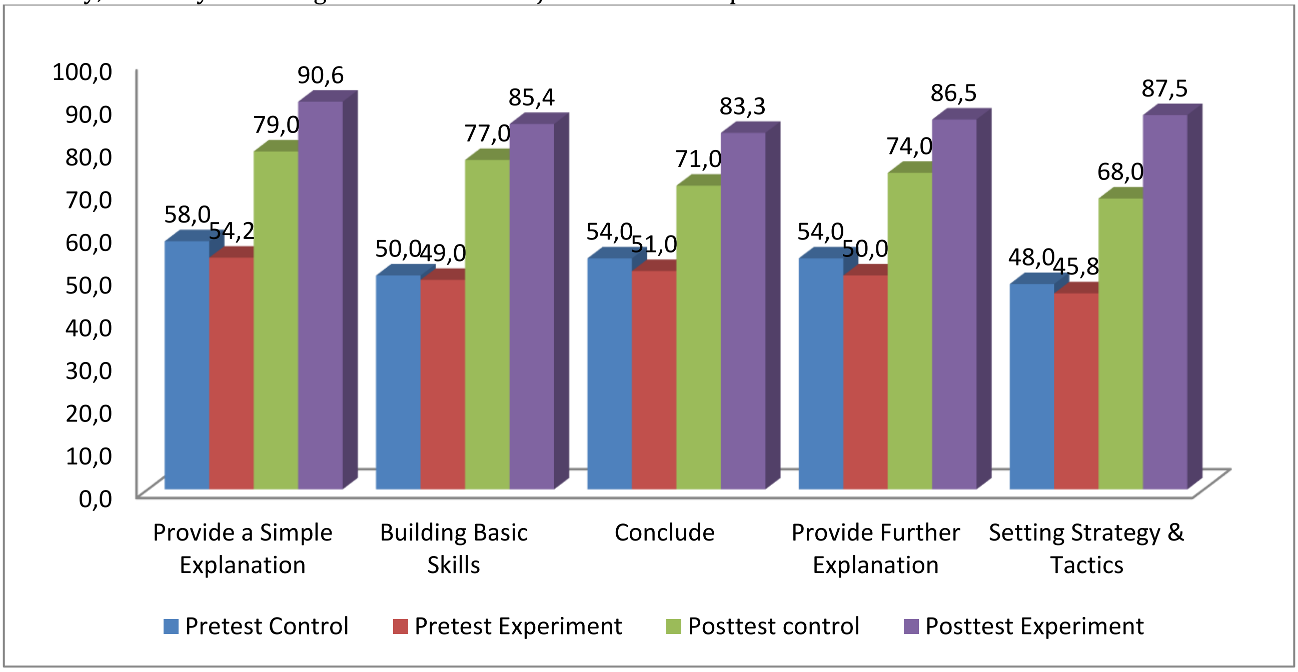

Figure 1. Diagram of Critical Thinking Ability Values for Each Indicator

The figure shows an increase in each indicator of students' critical thinking abilities from pretest to posttest in both samples. In the experimental group, the greatest improvement was in the ‘devising strategies and tactics’ indicator, rising from 48.0 to 87.5, while the smallest gain was in the ‘providing simple explanations’ indicator, rising from 58.0 to 90.6. This suggests that students' initial proficiency in ‘providing simple explanations’ was already relatively higher compared to the other indicators. Consequently, the improvement achieved in this indicator following instruction based on the ethnoscience-integrated problem-based learning model was less pronounced than in the others. Conversely, the ‘devising strategies and tactics’ indicator started from a relatively low baseline, resulting in a more substantial improvement after the implementation of the ethnoscience-integrated Problem-Based Learning model.

To examine the influence of the ethnoscience-based problem-based learning model on students' critical thinking ability, we conducted a hypothesis test. Before conducting the hypothesis test, we conducted prerequisite tests, namely normality and homogeneity tests. Tables 3 and 4 present the results of the normality and homogeneity tests.

Table 3. Data Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Critical Thinking Ability	Pretest Experiment	.129	24	.200*	.966	24	.578
	Pretest Control	.168	25	.068	.941	25	.154
	Posttest Experiment	.143	24	.200*	.936	24	.133
	Posttest Control	.200	25	.011	.948	25	.221

Table 4. Data Homogeneity

		Levene Statistic	df1	df2	Sig.
Critical Thinking Ability	Based on Mean	1.611	1	47	.211
	Based on Median	1.859	1	47	.179
	Based on Median and with adjusted df	1.859	1	46.540	.179
	Based on trimmed mean	1.636	1	47	.207

Because the research sample size was less than 50 students, the Shapiro-Wilk significance value was used to determine whether the data were normally distributed. This aligns with Ningsih et al., who state that there are two types of normality tests: the Kolmogorov-Smirnov test and the Shapiro-Wilk test; specifically, the Shapiro-Wilk test is used when the sample size is small (less than 50) [22]. Table 3 shows that the significance values for the pretest and posttest for both the experimental and control classes were greater than 0.05, indicating that both samples were normally distributed. Furthermore, Table 2 shows that the sig. value obtained was 0.211, which is greater than 0.05, indicating that both samples were homogeneous.

The next stage is to conduct a hypothesis test to determine whether applying the ethnoscience-based Problem Based Learning model significantly affects students' critical thinking ability. Table 5 shows the hypothesis test results.

Table 5. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Critical Thinking Ability	Equal variances assumed	1.611	.211	4.944	47	.000	12.867	2.602	7.632	18.102
	Equal variances not assumed			4.919	43.501	.000	12.867	2.616	7.594	18.140

Based on the table above, the sig value (2-tailed) is 0.000. This value is less than 0.05; therefore, the ethnoscience-based Problem-Based Learning model influences the critical thinking ability of MA Syaikh Zainuddin NW Anjani students.

The research results indicate that the implementation of an ethnoscience-based Problem-Based Learning (PBL) model positively influences students' critical thinking ability regarding the topic of buffer solutions. This is evidenced by the increase in the average critical thinking score from pretest to posttest: in the experimental class, it rose from 50.0 to 86.7, and in the control class, it rose from 52.8 to 73.8; however, the increase in the control class was lower than in the experimental class. This difference in improvement in critical thinking ability shows that instruction using the ethnoscience-based PBL model is more effective at developing students' critical thinking ability than the instruction implemented in the control class.

The experimental class improved its critical thinking ability because the PBL model places students at the center of learning by having them resolve real-world problems. The PBL model is a learning approach that encourages students to learn collaboratively in groups to solve real-world problems [23]. This finding is consistent with the constructivist principle underlying PBL [12], in which students actively construct knowledge through authentic, contextual problems.

When studying buffer solutions, students not only learn theoretical concepts but also encounter everyday problems. The concepts covered include the definition of buffer solutions, their constituent components, their working principles, and their roles in daily life. These concepts are abstract because they involve equilibrium reactions and changes in hydrogen ion concentrations that cannot be directly observed. Therefore, instruction should link microscopic, macroscopic, and symbolic concepts through contextual problems. Ethnoscience is integrated into the study of buffer solutions by highlighting local cultural phenomena, such as traditional food fermentation processes and the preparation of regional specialties. These problems encourage students to identify relevant information, analyze relationships between concepts, formulate solutions, and evaluate the results obtained. This process aligns with the characteristics of Problem-Based Learning (PBL), which fosters higher-order thinking skills, specifically, critical thinking abilities [24].

Integrating a local cultural context approach (ethnoscience) into the Problem-Based Learning framework can enhance students' critical thinking ability more effectively than conventional instruction. This effectiveness is reflected in improvements across all indicators of critical thinking ability, namely: 1) providing simple explanations, 2) building basic skills, 3) concluding, 4) providing further explanation, and 5) setting strategy and tactics.

Analysis of the ‘providing simple explanations’ indicator reveals an increase from 58.0 to 90.6; although this represents the smallest gain among the indicators, the result demonstrates that students possessed a relatively strong baseline ability prior to instruction. The improvement in this indicator reflects the students' growing capacity to identify problems, express opinions, explain discovered facts, and answer questions based on information gathered during the learning process. These skills developed because, during the problem-orientation phase of the PBL model, students encountered issues rooted in local cultural phenomena, prompting them to voice their views and explain these phenomena using their existing knowledge. Furthermore, the 'providing simple explanations' indicator also advanced during the second stage of the PBL model, organizing students for learning, where group discussions enabled students to gain a deeper understanding of the problems, thereby allowing their ability to explain phenomena to develop progressively. Through discussion activities, students do not merely receive information from the teacher but also actively engage by expressing opinions, presenting arguments, and evaluating the ideas of fellow group members. This process can help enhance students' critical thinking ability [25]. Furthermore, discussion methods can enhance student engagement and support the development of critical thinking skills through activities such as asking questions, expressing opinions, and responding to peers' ideas [26].

The 'building basic skills' indicator showed an increase from 49.0 to 85.4; this achievement reflects improved proficiency in gathering, identifying, and evaluating relevant information to serve as a basis for problem-solving. Throughout the learning process, students had the opportunity to seek information from various sources, observe phenomena related to local culture, and discuss their findings with group members. Students developed these skills during the third stage of the PBL model: guiding individual and group investigations. At this stage, the teacher instructed students to obtain accurate information, seek explanations for the previously formulated problems, and subsequently solve the tasks outlined in the student worksheets. The inquiry or investigative activities undertaken by students provide them with the opportunity to gain real-world experience regarding cultural phenomena in the community related to the subject matter as a foundation for contextual learning [27].

The 'conclude' indicator also increased, rising from 51.0 to 83.3; this achievement shows that students were able to draw conclusions based on facts and evidence gathered during the inquiry process. This ability developed through the third and fourth stages of the PBL model; during the inquiry phase, students analyzed data and linked the facts they discovered to scientific concepts. Utami and Astawan [28] describe the investigation stage as the core of the problem-based learning model; during this stage, the teacher encourages students to gather information, conduct experiments to obtain explanations and solutions, collect data, formulate hypotheses, and solve problems. During the results presentation phase, they articulated conclusions based on their group analysis. These activities trained students to formulate conclusions grounded in evidence rather than mere assumptions.

The 'provide further explanation' indicator demonstrates that students progressed in articulating arguments and justifying the solutions they derived. This is evidenced by an increase in scores from 50.0 to 86.5; this ability developed during the fourth phase of the PBL model, when students presented the results of their topic-specific discussions to the class, followed by a question-and-answer session. Lutfirohmatika and Pertiwi explain that presentations allow speakers to communicate ideas, thoughts, or information to an audience [29].

The 'setting strategy and tactics' indicator showed the greatest increase, rising from 48.0 to 87.5; this substantial gain indicates that students made significant progress in determining problem-solving strategies, identifying alternative solutions, and evaluating the steps taken to reach a solution. This improvement is linked to the fifth phase of the PBL model. During this stage, students reflect, assess the success of the strategies used, identify necessary improvements, and draw conclusions about the specific topics within the buffer solutions unit. Furthermore, group inquiry activities provide students with practical experience in planning their workflow and selecting appropriate strategies to solve the problems at hand.

Overall, the research results indicate that the ethnoscience-based problem-based learning model significantly affects students' critical thinking ability. Hypothesis testing using an independent samples t-test yielded a sig. (2-tailed) value of 0.000 (< 0.05). The results align with research [16], which states that implementing an ethnoscience-integrated problem-based learning model influences students' critical thinking ability on the topic of ecosystems.

Furthermore, research conducted by [17] indicates that the ethnoscience-based Problem-Based Learning (PBL) model influences the science learning outcomes of fourth-grade students in Cluster 5, Jatibanteng District. The development of PBL-based electronic worksheets (e-LKPD) integrating ethnoscience elements proved effective in enhancing critical thinking ability and received a highly positive response from students [30]. A systematic literature review by [31] concluded that PBL is one of the most effective ethnoscience-based learning models for enhancing students' critical thinking ability because it connects scientific concepts with local cultural contexts.
In the PBL model, students do not merely receive information from the teacher but actively identify problems, gather information, analyze data, formulate alternative solutions, and evaluate the solutions obtained. This aligns with the view of Agusdianita et al [32], who explain that the Problem-Based Learning (PBL) model is a problem-oriented instructional approach in which students are actively engaged in identifying, analyzing, and resolving the problems they encounter, this process aims to develop critical, analytical, systematic, logical, and creative thinking skills, enabling students to generate alternative solutions supported by

empirical evidence. Implementing the PBL model can enhance students' critical thinking ability, as students are directly involved in the learning process through problem-solving and inquiry activities [33]. When this process is integrated with the local cultural context through an ethnoscience approach, the issues being studied become more closely aligned with the students' lives. Linking this context to real-life experiences makes it easier for students to understand and connect scientific concepts while also fostering critical thinking. Integrating ethnoscience into instruction makes scientific concepts more contextual by linking them to the culture, traditions, and local wisdom that are close to students' lives. This approach not only enhances scientific literacy but also strengthens critical thinking ability through authentic learning experiences [34]. Syafitri et al [35] argue that this learning model encourages students to think through a problem-solving process centered on real-world issues relevant to them, while integrating local wisdom and knowledge from their surroundings, thereby positively impacting the enhancement of their thinking ability. Nevertheless, this study is limited by its relatively small sample size and its focus on a single school and a single chemistry topic; therefore, the findings should be generalized with caution and warrant replication across broader contexts. Despite these limitations, these findings suggest that chemistry teachers can adopt ethnoscience-based PBL as an alternative instructional strategy, particularly for abstract topics such as buffer solutions, by incorporating local cultural practices relevant to students' daily lives.

CONCLUSION

Based on the results and discussion, it can be concluded that the ethnoscience-based Problem-Based Learning model has a significant effect on the critical thinking skills of MA Syaikh Zainuddin NW Anjani students regarding the topic of buffer solutions; this is evidenced by the difference in mean scores between the experimental and control classes, and the hypothesis test results using an independent sample t-test showing a significance value of less than 0.05; Future research is recommended to explore the implementation of ethnoscience-based PBL across other chemistry topics and educational levels, as well as to examine its effect on other higher-order thinking ability.

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