



The Effect of Ethnochemical-Based Flipped Problem-Based Learning Model on Students' Chemical Literacy on Buffer Solution Material

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Abstract: This study investigates the effect of an ethnochemistry-based flipped problem-based learning (FPBL) model on students' chemical literacy in buffer solution material. The research employed a quasi-experimental design with pre-test and post-test control groups. Data were collected through chemical literacy tests and analyzed using MANOVA at a 5% significance level. The results revealed a significant difference in chemical literacy between students who learned through the ethnochemistry-based FPBL model and those instructed using a conventional scientific approach. The model contributed 23.5% to the improvement in students' chemical literacy, indicating a substantial effect. Furthermore, students exposed to the ethnochemistry-based FPBL model demonstrated enhanced ability to integrate chemical concepts with problem-solving and apply knowledge in practical scenarios. These findings highlight the effectiveness of incorporating ethnochemistry elements into flipped problem-based learning, providing a structured and culturally relevant approach that promotes deeper understanding of chemistry concepts. This study offers evidence that the ethnochemistry-based FPBL model can serve as an effective pedagogical strategy to enhance chemical literacy, suggesting its potential for broader application in chemistry education.

Keywords: Chemical Literacy; Ethnochemistry; Flipped problem based learning

Introduction

Effective chemistry learning should enable students to gain meaningful understanding from their learning activities (Nieswandt, 2007). Central to this goal is chemical literacy, which involves comprehending fundamental chemistry concepts, explaining phenomena, and applying chemistry knowledge to solve problems in daily life, thereby fulfilling societal responsibilities (Seery & McDonnell, 2013; Wiyarsi et al., 2021). Despite its recognized importance, students' chemical literacy remains low, particularly in applying concepts to real-world situations. This persistent gap highlights the need for instructional strategies that move beyond rote memorization toward deeper understanding and practical application.

The low level of chemical literacy can be attributed to conventional teaching practices that emphasize factual knowledge over conceptual understanding and problem-solving skills. Assessment methods have often reinforced this pattern, as students are rarely engaged with exercises that require analysis, reasoning, or the application of chemistry concepts (Shiddiqi et al., 2024). Consequently, students miss opportunities to develop higher-order thinking skills and meaningful learning in chemistry (Ayubi et al., 2025; Putri et al., 2024).

Problem-Based Learning (PBL) addresses these challenges by fostering critical thinking, problem analysis, independent information gathering, conceptual organization, collaboration, and communication skills (Chaniago et al., 2025; Günter & Alpat, 2017). Complementing this approach, the flipped classroom strategy delivers instructional materials prior

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to class, allowing classroom time to focus on discussion, problem-solving, and active application (Hu et al., 2018; Rahmi et al., 2021; Susanti & Pitra, 2019). The integration of PBL and flipped classroom strategies, referred to as the Flipped Problem-Based Learning (FPBL) model, has been shown to enhance science literacy, critical thinking, collaboration, and problem-solving ability (Capone et al., 2017; Paristiowati et al., 2015; Ramadhani et al., 2019).

Incorporating ethnochemistry into the FPBL model further improves learning by connecting chemistry instruction to local culture, traditional practices, and social issues (Ridwan et al., 2025; Sudirman et al., 2025). This approach introduces real-life examples that make abstract concepts more relatable, helping students link chemistry knowledge with their daily experiences and social environment (Konyefa & Okigbo, 2021; Sudarmin et al., 2018). By integrating cultural elements into the learning process, ethnochemistry-based FPBL facilitates students' understanding and application of chemical principles.

Although previous studies have demonstrated the effectiveness of PBL, flipped classrooms, and ethnochemistry individually, research on their combined effect on students' chemical literacy is limited. In particular, no study has explored the impact of an ethnochemistry-based FPBL model on learning buffer solution material at the high school level. Addressing this gap, the present study investigates the effectiveness of this integrated model, providing strategies to enhance chemical literacy, meaningful learning, and students' ability to apply chemistry concepts in everyday life.

Method

This study employed a quasi-experimental design with a pre-test post-test control group format (Sugiyono, 2016). Two classes of XI MIPA students at SMAN 1 Cangkringan, Kabupaten Sleman, Yogyakarta, were selected as the sample using random class selection. The study was conducted in February during the even semester of the 2023/2024 academic year. The experimental group received the ethnochemistry-based Flipped Problem-Based Learning (FPBL) treatment, while the control group was taught using a conventional scientific approach. Both groups were given a chemical literacy pre-test to assess their initial abilities. The treatment was implemented over several meetings, with each session lasting approximately 90 minutes, using buffer solution material as the subject of instruction. After completing the treatment, a chemical literacy post-test was administered to both groups. The research design is summarized in Table 1.

The population of this study consisted of all XI MIPA students at SMAN 1 Cangkringan. SMAN 1 Cangkringan was selected based on the availability of facilities and accessibility. The accessible population was

limited to the students of this school to ensure the validity of the study results.

Table 1. Research design

Group	Pre-test	Treatment	Post-test
Experiment	O	X ₁	O
Control	O	-	O

Description:

O : Chemical literacy ability test

X₁ : learning with FPBL model

- : learning with scientific approach

Data were collected using essay tests designed to measure chemical literacy skills. The instrument was validated theoretically by chemistry education experts and empirically through a pilot test outside the research sample. Empirical validation included construct validity, and reliability was assessed using Cronbach's alpha coefficient. The tests were administered under controlled conditions using a clear scoring rubric with multiple raters to ensure scoring consistency. The collected data were analyzed using MANOVA at a 5 percent significance level to determine differences in chemical literacy between the experimental and control groups. The analysis also assessed the effect size of the ethnochemistry-based FPBL model on students' chemical literacy.

Result and Discussion

The research was conducted in two XI MIPA classes that came from a homogeneous population. The two classes came from SMA Negeri 1 Cangkringan with 1 class as the experimental group, and 1 class as the control group. Each class received five meetings with an allocation of 2JP (2 x 45 minutes). The first meeting was conducted for the pre-test of chemical literacy skills, the second to fourth meetings for the learning process of experimental classes with the ethnochemical-based FPBL model and control classes with a scientific approach, and the last meeting for the post-test of chemical literacy of students after the learning process. The sample in this study amounted to 70 students, 34 experimental class students and 36 control class students. This research data is quantitative data in the form of chemical literacy scores.

Description of Pre-Test and Post-Test Scores of Students Chemical Literacy

The learning process using the ethnochemical-based FPBL model on buffer solution material provides better results in improving chemical literacy skills. This is evidenced by the average n-Gain score of chemical literacy which is higher in the experimental class of 0.609 than the control class of 0.490. The average score of students' chemical literacy skills in the experimental class and control class is described in Table 2.

Table 2. The average score of students' chemical literacy skills in the experimental and control class

Group	n	Average Score			Category
		Pre-test	Post-test		
Control	36	5.361	14.527	0.490	Moderate
Experiment	34	5.117	16.705	0.609	Moderate

The learning process using the ethnochemistry-based Flipped Problem-Based Learning (FPBL) model on buffer solution material demonstrated a greater improvement in students' chemical literacy compared to the control group. This is reflected in the average N-Gain score, where the experimental class achieved 0.609, higher than the control class at 0.490, indicating a moderate yet more substantial gain in the experimental group. The post-test average score in the experimental class (16.705) also surpassed that of the control class (14.527), confirming the effectiveness of the FPBL approach in enhancing students' understanding and application of chemical concepts. These findings are consistent with previous research showing that integrating problem-based learning with flipped classroom strategies can improve students' science literacy and problem-solving abilities (Capone et al., 2017; Ramadhani et al., 2019). Moreover, incorporating ethnochemistry provides culturally relevant examples that make abstract chemical concepts more meaningful, further supporting cognitive engagement and learning outcomes (Konyefa & Okigbo, 2021; Sudarmin et al., 2018).

Chemical Literacy Skills of Students in Experimental and Control Group

Differences in students' chemical literacy skills in the experimental group and control group were analyzed using the Test of Between-Subject Effect. The results of the analysis with the Test of Between-Subject Effect can be seen in Table 3.

Table 3. Test of between-subject effect results

Dependent Variable	Sig.	Partial Eta Squared	Decision
Chemical Literacy	0.000	0.235	H ₀ rejected

Based on the test results in Table 3, the significance value for the chemical literacy variable is 0.000 which means less than 0.05 (Sig. < 0.05), so H₀ is rejected. So it can be concluded that at the 5% significance level there is a very significant difference in the chemical literacy ability of buffer solution material between the experimental and control groups. The effective contribution given from learning with the ethnochemical-based FPBL model to chemical literacy can be obtained through partial eta squared data derived from the Test of Between-Subject Effect test in Table 3. Based on the results obtained, the ethnochemical-based FPBL model provides an effective contribution to

chemical literacy skills of 23.5% derived from the eta squared value of learning independence of 0.235 which is in the high category. This is supported by the average n-gain value in the experimental class which is higher than the control class.

The results of this study are in line with research conducted by Paristiowati et al. (2019), which showed that the PBL-Flipped Classroom model had an effect on students' science literacy in chemical reaction equation material. In line with this research, Muyassaroh & Herianingtyas (2023), also found that the implementation of flipped problem-based learning can improve the science literacy of prospective elementary school teachers. The key to success in using the ethnochemical-based FPBL model is to encourage learners to be more active in applying new information to various contexts creatively (Capone et al., 2017; Gultom & Rohaeti, 2024; Pebrianti & Suryani, 2024).

The PBL stages train learners to think critically and creatively in solving problems in everyday life, because critical and creative thinking are basic competencies for mastering science literacy (Rouf et al., 2021; Sanova et al., 2016; Shiddiqi, 2024). In addition, the implementation of ethnochemistry makes students gain real experience in the surrounding environment related to the culture of Yogyakarta. Ethnochemistry provides opportunities for students to understand the relationship between chemistry and their daily culture, and encourages creative thinking skills in finding solutions to problems that are closely related to the surrounding cultural reality (Christiana & Rohaeti, 2024; Yuliana et al., 2021).

Profile of Chemical Literacy Skills of the Experimental Group After Learning with Ethnochemical-Based FPBL Learning Model on Buffer Solution Material

The profile of chemical literacy after participating in learning in the experimental class is based on the average score of the chemical literacy post-test on buffer solution material. The resulting score is then made into several categories based on the ideal assessment. The average number of chemical literacy scores on buffer solution material in the experimental class was 16.70 which was included in the good category. The results of the chemical literacy profile analysis in the experimental class based on the post-test score results can be seen in Figure 1.

The analysis results show that the chemical literacy profile students after participating in learning with the ethnochemical-based FPBL model is mostly in the good category at 73.52%, while in the very good category at 11.76% and the average category at 14.70%. In this result there are no students who have a chemical literacy profile in the deficient and very deficient category. These results indicate that the ethnochemical-based FPBL model is proven to be able to train students' chemical literacy skills well. The average score of good chemical

literacy is due to learning activities based on real-world problems related to surrounding culture. Using the FPBL model, students must think critically, creatively, and innovatively by discussing with a group of friends in finding solutions to the problems presented (Ratih & Rohaeti, 2024; Usman et al., 2024; Yanti & Rahmad, 2023).

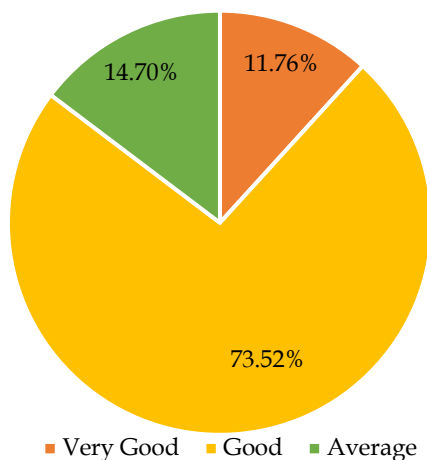


Figure 1. Chemical literacy profile of students in the experimental group

Research conducted by Pujiati & Retariandalas (2019), explained that science literacy can be improved well if teachers implement learning that contains aspects of science literacy through contextual materials that can stimulate students' higher order thinking skills. This is of course in accordance with the FPBL model which is a contextual learning model that allows students to explore and apply their knowledge and skills to solve problems that exist in the real world (Arif et al., 2024; Hajeniati & Kaharuddin, 2022; Muhartini et al., 2023). Integration of learning with surrounding culture also makes students more interested in the learning process and more aware of culture. In addition, students who can connect the concept of material received at school with the original knowledge of the community can be said to have a high level of chemical literacy with the formation and development of character (Januarti & Mulyadi, 2024; Perwitasari et al., 2016).

The profile of chemical literacy skills can also be reviewed based on competency aspects consisting of four indicators, namely, interpreting data and facts scientifically, compiling scientific inquiry, evaluating scientific investigations, and explaining phenomena scientifically. The results of the analysis of the competency aspects of chemical literacy in this study can be seen in Figure 2.

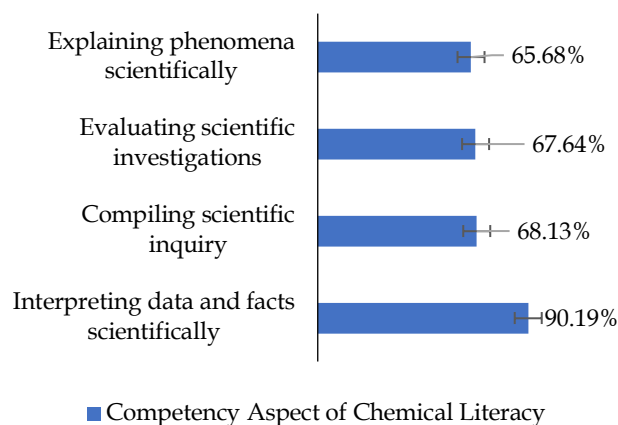


Figure 2. Chemical literacy profile based on competency aspect

The competency aspect is an aspect that will direct learners to ask questions, investigate, and evaluate them. Indicators in the competency aspect in this study are divided into four including, explaining phenomena scientifically, evaluating scientific investigations, compiling scientific inquiry, and interpreting data and facts scientifically. The indicators in this aspect were then analyzed further, with the indicator that got the highest percentage was interpreting data and facts scientifically with a percentage of 90.2%. This shows that most students have been able to give meaning to a phenomenon and make conclusions on the scientific evidence found (Anggraeni et al., 2023; Islakhiyah et al., 2017; Mellyzar et al., 2022). Evidently based on the exercises of the questions that have been given, students are able to answer confidently and correctly. For example, learners are given data on the results of a buffer solution experiment to which a small amount of acidic, basic, and water solutions are added, they are able to identify the characteristics of buffer solutions and which samples contain buffer solutions.

Furthermore, the indicator of the competency aspect that has the lowest percentage is the aspect of explaining phenomena scientifically with a percentage of 65.68%. This is evident from the answers of students who are still too general, have not explained in detail, and only focus on the core concepts they have. One example of a question with an indicator of explaining phenomena scientifically is "Why can eye drops relieve stinging and redness in the eyes?" Most learners answer "Because it contains buffer solution." The answer given is not wrong, but the explanation is incomplete, based on the discourse given, the pH atmosphere in the eye drops is adjusted to human pH conditions so as not to cause stinging in the eyes, which is around 7.4. The answer shows that students have not been able to fully explain scientific phenomena and relate them to the surrounding life. To improve the ability to explain scientific phenomena, learners need to be accustomed to connecting their knowledge with real-life phenomena

(Widowati & Agustini, 2025). In this study, habituation has not been implemented due to the short research time.

Conclusion

The findings of this study indicate that the ethnochemistry-based flipped problem-based learning (FPBL) model has a significant effect on students' chemical literacy in buffer solution material. Students who learned through the ethnochemistry-based FPBL model demonstrated higher chemical literacy compared to those taught using a conventional scientific approach. These results suggest that integrating ethnochemistry into a flipped problem-based learning framework can effectively enhance students' understanding and application of chemical concepts. The study provides evidence that the FPBL model offers both theoretical and practical benefits for chemistry education by promoting active engagement, critical thinking, and problem-solving skills. For future research, it is recommended to explore the application of ethnochemistry-based FPBL in different topics or educational levels, as well as to investigate its impact on other learning outcomes, such as higher-order thinking skills or student motivation.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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