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Analysis of Students Chemical Literacy through Ethnochemistry Learning in Material Colligative Properties of Solution

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Abstract: The industrial revolution in the 21st century demands the creation of a generation that is responsive to change and has the competencies of Critical Thingking, Creative Thingking, Communication, and Collaboration (4C). the contextual learning process based on ethnochemistry is expected ti increase students' motivation and interest in learning chemistry. Chemistry subjects that are classified as difficult and can be linked to local culture are the colligative properties of solutions. This study aims to analyze chemical literacy through learning with an Ethnochemical approach to the material of colligative properties of solutions. The research method used is quantitative descriptive research. Data collection using a test method, the test method is in the form of multiple-choice chemical literacy questions with a total of 10 validated questions and has a reliability index in the moderate category. The test method aims to determine students' chemical literacy in terms of content, context, and competence. The results of the study showed that the average chemical literacy of students in terms of content aspects was 49.2%; context aspects of 40.4%, and competency aspects of 50.6%. Th e average chemical literacy from these three aspects is categorized as "Not Enough". The results of the study concluded that chemical literacy in ethnochemistry-based learning is in the "Not Enaough" category. The recommendation from this study is the need for innovation in chemistry learning through integration between ethnochemistry and STEM as well as the development of teaching materials in the form of ethnochemistry-based books that support the learning process.

Keywords: *Colligative properties of solutions, Chemical literacy, chemistry learning, Ethnochemistry.*

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1. Introduction

The industrial revolution in the 21st century has become a benchmark for evaluating the education system which prioritizes the demand for creating a high-quality generation. The learning process is part of the education system which has undergone significant changes as a result of the impact of the industrial revolution. 21st century learning requires complex stimuli (Supena et al. 2021; González & Ramírez, 2022). This complexity, consisting of affective, cognitive and psychomotor, is the focus domain in learning in the 21st century (Akimov et al. 2023). One of the changes in the learning system in the 21st century is student-centered learning and the meaningfulness of learning (Mardhiyah et al. 2021; Handa & Talisayon, 2023). Contextual-based learning is a strategy to provide interest, motivation, train thinking, and improve student learning outcomes. This is because scientific concepts are presented from experiences or daily life activities experienced or recognized by students (Pursitasari et al. 2019; Prins et al. 2018). Contextual-based learning provides a picture of real problems and requires students to provide ideas for overcoming problems, especially Natural Sciences.

One of the fields of science is chemistry. Childs & Sheehan (2009) and Woldeamanuel et al. (2014) reported that chemistry is one of the subjects that is considered the most difficult because it is influenced by several factors, namely scientific language which is relatively high and difficult to understand, as well as the complexity of studying chemistry itself. These obstacles are the initial factors in realizing *Critical Thinking, Creative Thinking, Communication* and *Collaboration* (4C) oriented learning. These fundamental problems need to be studied more deeply so that they do not result in complex problems.

Pursitasari et al. (2019) revealed that students' thinking processes are the first step to understanding a concept. Systematic thinking in understanding the essence of concepts such as identifying problems and solving problems, as well as drawing conclusions based on evidence will result in students having good literacy. Assessment of Indonesian students' literacy has been measured through their participation in *the Program for International Student Assessment* (PISA). This program focuses on three evaluations, namely scientific literacy, mathematics literacy and reading literacy. However, the results of the PISA assessment in 2022 show that the scientific literacy of Indonesian students is not yet satisfactory with a score of 383. Literacy in science learning includes chemical literacy.

Chemical literacy includes the chemical knowledge and skills needed to understand chemistry-based social scientific issues (Kohen et al. 2020). PISA provides an assessment framework such as explaining scientific phenomena, evaluating data and drawing conclusions sequentially based on real evidence. So, students who have good chemical literacy will be able to do PISA questions well. On the other hand, students' low chemical literacy will have an impact on their difficulty in working on PISA questions. Le Hebel et al. (2019) added that the difficulty in working on PISA questions was due to the questions being unfamiliar to students, which had an impact on local perspectives and limited thinking processes.

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Therefore, questions that require increased scientific literacy, especially chemistry subjects, need to be practiced during the learning process.

Contextual-based learning is an effort to increase students' chemical literacy (Lidiawati et al. 2021; Pursitasari et al. 2019; Hadiprayitno et al. 2023; Tsadik Getu et al. 2024). Context-based learning seeks to correlate indigenous knowledge that develops in society with chemistry learned at school (Kusniati et al. 2023). Ethnochemistry is a science that connects cultural sciences and chemistry. Sutrisno et al. (2020); Zidny & Eilks (2022) revealed that ethnochemistry is a branch of science that discusses cultural practices that describe the chemical practices of chemically related cultural groups and can be identified as the study of chemical ideas that can be found in any culture. Integration between chemistry and local culture is an innovative approach in chemistry learning (Chibuye & Singh, 2024). This approach can be done to preserve cultural heritage and improve student competence in several aspects. Several studies have suggested that the positive impact of ethnochemistry on learning includes improving critical thinking skills (Rahmawati et al. 2019), problem-solving skills (Wahyudiati, 2024), chemistry learning outcomes (Wardhani et al. 2023), scientific explanation skills (Wiratma et al. 2023), and changes in student attitudes (Singh and Chibuye, 2016). The ethnochemical approach has made a significant contribution to the development of student competence in cognitive, skill, and affective aspects (Fasasi, 2017). However, there has been no research that integrates ethnochemistry-based learning with chemical literacy. This study will analyze how students' chemical literacy skills are after learning with an ethnochemical approach (Botha 2012). This study is expected to strengthen empirical evidence and expand the application of ethnochemistry in chemistry learning.

Competencies that can be improved through ethnochemistry-based learning are the first step to realizing 4C-oriented chemistry learning and to preserve regional culture through students' chemical literacy. The era of globalization has an impact on students' potential in maintaining regional identity and preserving it (Handayani et al. 2023), empowering human resources holistically to address developments (Sjöström et al. 2024). Project-based learning can be used as a method to involve students in learning and can provide constructive actions in preserving culture.

Seruyan is a district in Central Kalimantan which is rich in local culture, such as the residents’ habits of processing salted fish, jaruk (a typical regional pickle), making brown sugar, tempuyak and smoking fish. The chemical concept that can be correlated to local culture is the Colligative Properties of Solutions. The submains of this concept are vapor pressure reduction, boiling point elevation, freezing point depression, and osmotic pressure. Pratiwi et al. (2023) emphasized that concept of colligative properties of solutions is a concept that is difficult for student to understand. One of the cause is the lack of interest in studying chemistry and teachers’ misconceptions in explaining concepts and teachers’ lack of multi-representation analogies (Zepeda et al. 2020). The purpose of this study is to analyze the chemical literacy profile of students after ethnochemistry-based learning.

2. Method

Analysis of students' chemical literacy is revealed through quantitative-based descriptive research (Creswell, 2012). This research took place at SMAN 1 Danau Seluluk. The data in this study were obtained from the results of a chemical literacy test given to 22 students in class 12-science, consisting of 7 male students and 15 female students who had studied the material on the colligative properties of solutions.

The research method used was a case study with a research design, namely One-shot Case Study. This research design was used to understand the phenomenon initially or in depth related to students' chemical literacy after carrying out ethnochemistry-based learning. Data collection was carried out using a test method to determine students' chemical literacy and a questionnaire sheet to determine students' responses to the learning that had been carried out.

The stages in this study can be show in Figure 1. The stages in this research can be shown in Figure 1. Description of the activities at each stage of the research can be seen in the following explanation:

1. **Preliminary Stage**
   Some activities carried out at this stage include identifying problems from learning that has been carried out and literature studies to find and formulate problems in research.
2. **Preparation Stage**
   At this stage, the activities carried out include compiling learning devices, compiling instruments containing chemical literacy, instrument trials and instrument validation.
3. **Implementation Stage**
   The implementation stage is carried out by implementing ethnochemistry-based learning on the colligative properties of solutions. The total number of meetings used for the study was 3 times with a time of 2 x 45 minutes.
4. **Final Stage**
   The activities carried out at this stage are data collection, data analysis, and reporting.

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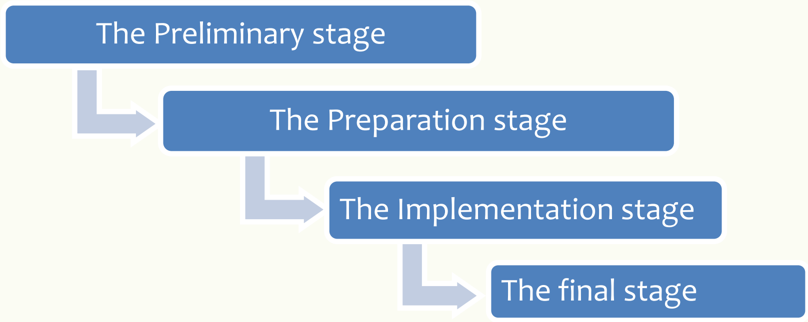

Figure 1. Research Stages

The instrument used was a chemical literacy test based on ethnochemistry with 10 valid multiple choice questions with a reliability coefficient of 0.642 in the currently category (Table 1). The chemical literacy questions consist of context, content and competency.

Table 1. Reliability Criteria for Question Items

Reliability of Question Items	
Coefficient	Category
$0.00 \le r_i < 0.50$	Low
$0.50 \le r_i < 0.70$	Currently
$0.70 \le r_i < 0.90$	Tall
$0.90 \le r_i \le 1.00$	Very high

(Hinton, 2004)

Data were analyzed using descriptive statistics by calculating the average of research results in percent (%).

$$\text{Student Literacy (\%)} = \frac{Correct\ score\ count}{Maximum\ Score\ Amount} \times 100\ \%$$

Students' chemical literacy results are categorized based on Table 2.

Table 2. Chemical Literacy Criteria

Scientific Literacy Value (%)	**Criteria**
80-100	Very good
66-79	Good
56-65	Enough
40-55	Not enough
30-39	Very less

(OECD, 2017)

3. Result and Discussion

The results of the analysis of students' chemical literacy on the Colligative Properties of Solutions material through ethnochemical-based assessment questions can be seen in Figure 1.

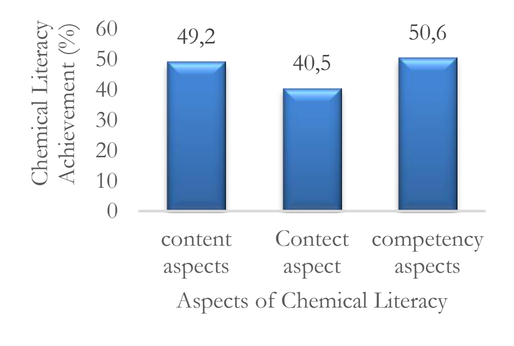

Figure 1. Overall Student Chemical Literacy Achievement

Figure 1 shows the average student chemistry literacy of 46.77% in the “Not Enough” category. The reason why students have low chemical literacy scores is influenced by students not being able to connect and interpret the scientific concepts of chemistry that have been studied at school with the scientific concepts of chemistry that are developing in society. Another cause is ethnochemical-based questions which tend to be unfamiliar to students. because students are still unfamiliar with the form of questions based on ethnochemistry, as well as students' low ability to correlate, identify problems, scientific explanation skills, as well as students' interest and motivation in understanding chemistry.

These problems can be overcome by students through reading habits, interpreting reading results by rewriting their reading results (Cigdemoglu & Geban, 2015). Low chemical literacy can also be influenced by their ability to combine procedural knowledge and content knowledge (Fadly et al. 2022). This inequality occurs when students understand chemistry better without experiments and conversely, there are students who easily understand chemistry when supported by experiments. The learning process using an ethnochemical approach using material analogies and laboratory experiments needs to be taught repeatedly to students in order to get used to it. According to research conducted by Meristin & Rosita (2023), ethnochemistry-based learning can increase chemical literacy with an N-Gain of 0.25 with low criteria. Therefore, it is necessary to develop learning tools that are able to support teaching so that chemical literacy can increase.

Students who have good chemical literacy are because students are able to correlate the chemical understanding they have learned with the ethnochemical-based chemical problems given. Apart from that, students are also able to identify problems in detail through chemical literacy-based test questions to be able to solve the problems given. This shows that these students have critical thinking skills, problem solving, and scientific explanation skills (Rahmawati et al. 2019; Wahyudiati, 2024; Wiratma et al. 2023). Sudarmin et al. (2018) revealed that local culture-based learning can increase students' cultural awareness by remembering

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history and interpreting history through a scientific approach. So, indirectly, ethnochemistry-based learning will have an impact on *education for sustainable development* (ESD) (Puspita et al. 2024; Ekamilasari & Pursitasari, 2021; Sholahuddin et al. 2021; Mogren & Niklas, 2017).

Chemical Literacy Content Aspects

Chemical literacy data on the content aspect was obtained from analysis of students' answers to questions developed from four (4) indicators, namely: (1) Boiling point increase, (2) Vapor point decrease, (3) Freezing point decrease, and (4) Pressure osmotic. Chemical literacy data on the content aspect can be seen in Figure 2.

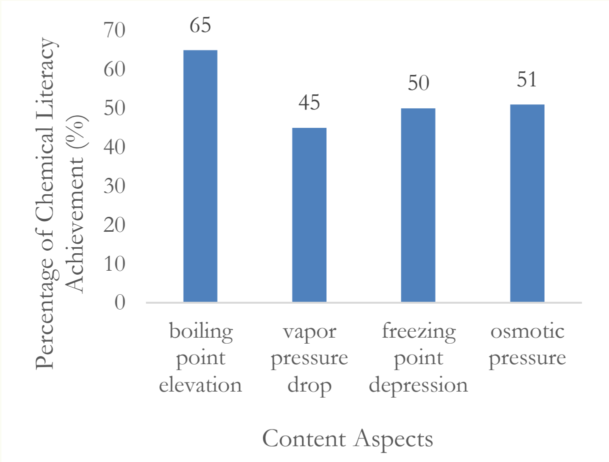

Figure 2. Achievement of Chemical Literacy in Content Aspects

Figure 2 provides information that overall chemical literacy in the concentration aspect is 52.75% which is categorized as "Not Enough". The highest percentage in this aspect is found in the "boiling point increase" indicator. Meanwhile, the lowest percentage is in the vapor pressure reduction indicator. The high percentage of chemical literacy in the boiling point elevation indicator is because the questions were developed on an ethnochemical basis with the topic of making jaruk or pickled fruit using salt in making pickled sauce. In this indicator, students are able to connect original knowledge that develops in society with chemical concepts that students have received, so that this results in an increase in students' chemical literacy (Perwitasari et al. 2016).

Students who have poor chemical literacy in the content aspect are because students have not been able to correlate content knowledge in problems that are relevant to everyday life (Fadly et al. 2022). Building and developing students' scientific literacy requires contextual-based learning that is concept-oriented to the problems students experience in everyday life (Pursitasari et al. 2019; Guth & Van, 2023; Fayzullina et al. 2023). These problems do not come from students alone but there is influence from teachers during the learning process. Teachers do not make it a habit to analogize chemical problems with an ethnochemical approach which has an impact on students' lack of knowledge in solving problems in their daily lives.

This is in accordance with research conducted by Sumarni et al. (2017) that prospective teachers still do not have good chemical literacy skills in the content aspect because the learning they receive does not link material concepts with problems in everyday life.

Context Aspects of Chemical Literacy

The context aspect contains questions that discuss local culture which is correlated with scientific knowledge on the concept of colligative properties of solutions. It is very important to study this aspect because it can provide opportunities and innovation in maintaining regional identity and increasing student literacy (Heliawati et al. 2022; Chi et al. 2023). Chemical literacy data on the context aspect was obtained through questions developed using an ethnochemical approach. Chemical literacy in the context aspect can be seen in Figure 3.

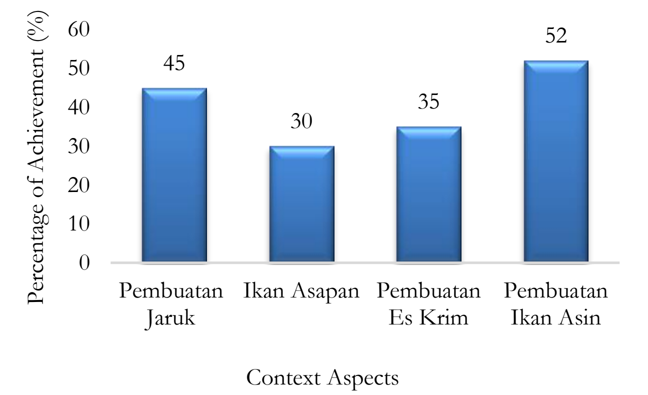

Figure 3. Percentage of Chemical Literacy Achievement in Context Aspects

Overall chemical literacy in the context aspect is 40.5% in the "not enough" category. The highest percentage of chemical literacy in the context aspect is in indicator 4, namely osmotic pressure with the focus of the question determining the osmotic pressure of the solution in the process of making salted fish. This question has an ethnochemical content where students are required to be able to determine the properties and uses of salt in making salted fish from haruan fish. This indicator has higher chemical literacy than other indicators, because the students' parents produce a lot of salted fish from fishing or fishing in the Seruyan river. So, students can interpret the problem well even though it is still categorized as inadequate. Nuroso et al. (2018) emphasized that learning based on local wisdom allows students to integrate scientific concepts into problems in everyday life.

Understanding chemical literacy in this context aspect becomes students' capital in working on PISA evaluation questions. Because in the PISA questions there are many questions from contextual problems. Ethnochemistry-based problems are the first step to train students' chemical literacy so that they can be a solution in increasing the scientific literacy of Indonesian students. Wardani & Anggraeni (2020) informed that guided inquiry-based learning can significantly increase students' chemical literacy. Chemical literacy will tend to increase if

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students' interest and motivation in studying chemistry also increases. So innovation is needed in chemistry learning to increase chemical literacy through inquiry-based learning.

Competency Aspects of Chemical Literacy

Chemical literacy has three competency aspects, namely: (1) evaluating and designing scientific investigations; (2) explain phenomena scientifically; and (3) interpreting scientific data and evidence. Chemical literacy data for each aspect of competency is in Table 3.

Table 3. Students' chemical literacy in terms of competency aspect

No	Competency Aspects	Percentage
1	Evaluate and design scientific investigations	45%
2	Explain phenomena scientifically	51%
3	Interpret scientific data and evidence	54%
	Average	50%

Table 3 informs that chemical literacy in the overall competency aspect is 50% in the "not enough" category. The indicator with the highest percentage is indicator 3, namely interpreting scientific data and evidence, while the lowest percentage is the indicator evaluating and designing scientific investigations. Overall chemical literacy in the competency aspect is still in the "not enough" category. One of the causes of this problem is that students' ability to identify variables in scientific investigations is still relatively low (Imansari et al. 2018). Another cause lies in the low level of content (knowledge) that students possess, so that they have difficulty interpreting problems and therefore tend to use local and non-multi-representative thought processes for the ethnochemical problems given.

Indicators for evaluating and designing scientific investigations, this indicator is still classified as "poor". This low indicator in the competency aspect can be resolved through a procedural-based learning process that requires students to observe and carry out contextual-based experiments. Procedural knowledge and content knowledge provide different meanings, so educators need to strike a balance in the learning process so that these two competencies can increase which will have an impact on increasing chemical literacy (Fadly et al. 2022; Madden et al. 2023).

Performance-based learning requires students to connect content knowledge with knowledge gained from practical results. Thus, through this learning, students will be trained to evaluate work procedures that have been carried out and recommend new work procedures to find concepts or improve concepts appropriately (Komariyah & Karimah, 2019). This low indicator is a finding to strengthen the PISA results that science learning in Indonesia has not succeeded in improving students' scientific literacy skills in content and context aspects.

Indicators explain phenomena scientifically, these indicators are still classified as "poor". The low level of this indicator can result from the lack of students' ability to interpret ethnochemical-based questions, the lack of an ethnochemical approach to chemistry learning in class carried out by teachers, and the lack of students' reading literacy due to low motivation and interest. The phenomena presented to students are very familiar to them, but students' ability to scientifically integrate indigenous knowledge in local culture according to the concept of colligative properties of solutions is still very difficult.

The low percentage of this indicator can also occur because students' initial knowledge of the concept of colligative properties of solutions and prerequisite material is quite low (Sariati et al. 2020). Explaining phenomena scientifically requires complex competencies, one of which is thinking competency for problem solving and scientific argumentation skills. This competency will not emerge if it is not trained on students, so learning that supports increasing this competency is learning with a STEM (Science technology engineering and mathematics) approach recommended by Gulen (2018).

The indicator interprets data and scientific evidence, this indicator is higher than other indicators in the competency aspect but is still relatively lacking. Achievement in this indicator is reflected in students' demands to interpret scientific evidence and draw conclusions by interpreting data from the test items. The next achievement is the use of scientific evidence to identify assumptions, evidence and reasons for the conclusions drawn in solving problems on the concept of colligative properties of solutions. Achievements on this indicator are still relatively low, this is shown in the percentages resulting from data processing.

This problem is caused by learning in Classes generally place less emphasis on process or performance but rather on the action tendency to transfer knowledge verbally which results in students only being required to memorize. This indicator also requires students to understand the phenomenon given so that students can provide analysis of the data or situations given in the questions. After students understand and interpret the phenomena given, students can easily interpret the data or situations given because they are able to connect the variables that have been understood.

The low percentage of chemical literacy in the material on the colligative properties of solutions from these three aspects (content, context and competency) is largely influenced by external and internal factors in the learning process. External factors are influenced by teacher explanations and teaching resources. Meanwhile, internal factors are influenced by students' interest, motivation, initial abilities, and concern in studying chemistry. Innovation in chemistry learning needs to be done in a modern way such as connecting the subject with entrepreneurship as recommended by Ahmad et al. (2024) and project -based (Seprianto & Hasby 2023). Through learning with an ethnochemical approach supported by STEM performance to develop local products (Primadianningsih et al.

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2023; Sjostrom et al. 2018). Students are given the freedom to explore work procedures in accordance with chemical rules to make products and then buy and sell them. Combination teaching materials from ethnochemistry and STEM need to be developed as a first step in guiding students to study chemistry in depth and evaluate concepts through experiments.

4. Conclusion

Based on research that has been conducted, it was found that the average result of students' chemical literacy in the content aspect was 49.2%, which was categorized as "not enough". Students' chemical literacy in the context aspect is 40.5% which is categorized as "not enough". Students' chemical literacy in the competency aspect is 50.6% which is categorized as "not enough". The average overall achievement of students' chemical literacy is in the "poor" category. The recommendation from this research is that it is necessary to develop teaching materials in the form of textbooks that combine ethnochemistry and STEM in order to provide innovation in learning tools and increase chemical literacy.

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