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Development of a Culturally Contextualized Chemistry Literacy Test Based on West Kalimantan Culture on Thermochemistry Topics

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Abstract

The aim of this research is to produce a chemical literacy assessment instrument based on cultural context for high school students on the topic of thermochemistry. The instrument development was carried out by constructing and validating the culturally contextualized chemical literacy test through the following stages: (1) identification of aspects and indicators of culturally based chemical literacy; (2) construction of the assessment instrument; (3) theoretical validation; (4) empirical validation; (5) reliability testing; and (6) difficulty level analysis. Data were analyzed using the Winsteps application and interpreted through the Rasch Model. The developed instrument consists of 12 items encompassing four chemical literacy indicators: Chemical Knowledge Concept, Chemistry in Context, Higher-Order Thinking Skills, and Attitude. The cultural context includes four West Kalimantan cultural themes: Dayak traditional tuak drinking, betel chewing tradition, nasi hadap-hadapan ceremony, and the karbit cannon festival. Validity was confirmed through Outfit MNSQ, Outfit ZSTD, and Point Measure Correlation (Pt. Mean Corr) values. Reliability analysis showed a Cronbach's alpha of 0.56 (moderate), person reliability of 0.68 (moderate), and item reliability of 0.95 (very high). The instrument covers various difficulty levels: easy (1 item), moderate (9 items), and difficult (2 items), indicating a well-distributed test construction.

Keywords: *Chemical literacy, Culturally contextualized, Test instrument, Thermochemistry*

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INTRODUCTION

One of the objectives of chemistry education is to foster students' critical thinking skills to analyze and evaluate scientific issues and phenomena in daily life (Kemenristekdikti, 2024). This goal can be achieved, in part, by developing students' chemical literacy skills. Chemical literacy not only makes students more critical and creative, but it also assists them in making informed decisions to solve everyday problems based on knowledge (Cigdemoglu et al, 2017; Wiyarsi et al, 2021). Responsible citizens need to possess chemical literacy, critical thinking, and environmental awareness to make sound decisions for both society and personal life (Sjöström, 2024).

However, international science literacy surveys, such as the Programme for International Student Assessment (PISA), indicate that Indonesian students' science literacy skills, including chemistry, remain below the international average. A study by Yustin and Wiyarsi (2019) revealed that Indonesian students' chemical literacy is still low, particularly in connecting and analyzing scientific information. Research by Mellyzar et al (2022) found that the average pretest score for students' chemical literacy on chemical bonding was 18.8 and 15.2, both classified as very low. Wibowo and Ariyatun (2020) also found that chemical literacy in a senior high school in Indonesia was still low, as students struggled to communicate and connect their understanding with broader scientific contexts and faced difficulties in applying abstract and complex chemical concepts. The low level of chemical literacy indicates that students still encounter challenges in applying chemical knowledge to solve problems encountered in everyday life (Hatimah & Khery, 2023). Low science literacy makes students less responsive to problems and changes in their environment, less adept at utilizing scientific knowledge in daily life, struggling with problem-solving, and slow decision-making (Yusmar & Fadilah, 2023).

The factors contributing to the low levels of chemical literacy among students include their lack of familiarity with solving science literacy tasks in chemistry education, as they tend to focus more on memorizing content, which hinders their ability to understand and apply the concepts in everyday life (Ihsan & Jannah, 2021). Teachers who do not adequately train students to solve science literacy problems and rarely encourage them to develop concepts are also factors contributing to the low science literacy of students (Yusmar & Fadilah, 2023). Non-contextualized teaching leads students to perceive science, including chemistry, as a subject that is difficult to understand because it is not related to real-life situations (Fuadi et al, 2020).

This highlights the need for efforts to develop instruments and teaching strategies that can enhance students' science literacy skills, particularly in chemistry. The development of test instruments to enhance chemical literacy has been widely conducted, such as the study by Lukman et al (2022), which developed a chemical literacy test instrument on colloid topics; the study by Ariefiani & Laksono (2024), which developed a test instrument to measure critical thinking skills and chemical literacy on reaction rate topics; and the study by Yandiani et al (2021), which developed a test instrument to assess students' analytical thinking skills and chemical literacy on colligative properties of solutions. However, in these studies, the test instruments mainly focused on everyday phenomena familiar to students. To date, no researchers have developed chemical literacy test instruments that are linked to cultural contexts.

One approach that can be employed to enhance students' chemical literacy is by integrating local cultural contexts into chemistry instruction. Instruction that incorporates local wisdom and cultural elements has the potential to provide deeper meaning and enhance science literacy (Kristansto et al, 2024). Sanova et al (2023) research revealed that culture-based instruction can improve students' chemical literacy, making learning more meaningful. This integration makes learning more relevant to students' lives and enriches their understanding of local wisdom. Chemistry instruction linked to culture can foster students' curiosity about local culture (Anggreni et al, 2023).

With its rich cultural diversity, West Kalimantan provides various contexts that can be integrated into chemistry education. For instance, the traditions of the Dayak and Malay communities related to food processing, using natural materials, and managing natural resources can serve as contextual elements in the teaching of thermochemistry. Using local cultural contexts is expected to increase student engagement in learning and facilitate their understanding of abstract chemistry concepts, particularly in thermochemistry. Thermochemistry is often considered difficult and abstract by students (Lestari & Muchlis, 2021), thus requiring teaching approaches that can transform these abstract concepts into more concrete forms that are easier for students to grasp (Anggraini & Yusmaita, 2021). Thermochemistry instruction can be linked to one of the cultural practices in West Kalimantan, namely the Meriam Karbit Festival. Connecting the Meriam Karbit Festival with thermochemistry content can make the material more tangible, as students directly experience it. This aligns with the statement by Dewi et al (2019) that the use of culture in education can enhance students' understanding of concepts in a comprehensive, meaningful, authentic, and relevant manner.To facilitate culture-based learning, a valid and reliable assessment instrument is required. This instrument measures students' understanding of chemistry concepts and their ability to relate these concepts to local cultural contexts.

This study aims to develop a valid and reliable West Kalimantan Culture-Based Chemical Literacy Test. Using a research and development methodology, the resulting instrument is hoped to measure students' chemical literacy skills comprehensively. Additionally, this instrument is expected to serve as a reference for chemistry teachers in designing more contextual and relevant learning experiences for students.

METHOD

The development of the Test of Chemical Literacy based on Culture (TCLbC) instrument was carried out in accordance with Trochim's research (1999) and considered the recommendations by Dalgety, Coll, and Jones (2003) regarding the theoretical framework and construct validity concept. To ensure content validity, the researcher outlined the theoretical framework of chemical literacy as the basis for constructing the test items, which were then consulted with experts.

The validity was conducted in two stages: theoretical validity and empirical validity. Theoretical validity refers to validation conducted through expert judgment. The revisions resulting from the theoretical validity were then subjected to empirical validity testing. Empirical validity was conducted through a direct trial with senior high school students. The trial results were then analyzed to determine whether each statement in the questionnaire was valid. The empirical validity results were analyzed using Winsteps. The chemical literacy test items are considered valid based on Rasch Model analysis if they meet the following criteria (Sumintono & Widhiarso, 2015): (1) The outfit mean square (MNSQ) value falls within the range of 0.5 < MNSQ < 1.5; (2) The outfit Z-Standard (ZSTD) value falls within the range of -0.2 < ZSTD < +2.0; (3) The point measure correlation (Pt Mean Corr) value falls within the range of 0.4 < Pt Ukur < 0.85. An item is considered valid if it meets at least two of the above criteria (Boone et al., 2014).

The reliability of the TCLbC instrument in this study was analyzed using the Winsteps program by examining the Cronbach's coefficient, person reliability, and item reliability. The instrument's reliability is considered high when the reliability coefficient approaches 1.00, and conversely, if the coefficient approaches 0, the reliability is considered low. The criteria for Cronbach's alpha reliability values can be seen in Table 1 (Arikunto, 2010). The values of person and item reliability can be seen in Table 2 (Sumintono & Widhiarso, 2015). The difficulty level of the instrument was determined using the Rasch model. The difficulty of each item was categorized based on the logit measure and the logit item's standard deviation (SD) and divided into several categories, as presented in Table 3 (Adedoyin & Mokobi, 2013).

Table 1. Cronbach's alpha reliability value

Reliability Coefficient Value	**Criteria**
$0,80 < \alpha \leq 1,00$	Very High
$0,60 < \alpha \leq 0,80$	High
$0,40 < \alpha \leq 0,60$	Moderate
$0,20 < \alpha \leq 0,40$	Low
$\alpha \leq 0,20$	Very Low

Table 2. Pearson and item reliability values

Reliability Coefficient Value	**Criteria**
< 0,67	Weak
0,67 – 0,80	Moderate
0,81 – 0,90	Good
0,91 – 0,94	Very Good
> 0,94	Excellent

Tabel 3. Logit measure categories

Logit Measure Value	**Item Difficulty Interpretation**
$x > 1$	Very Difficult
$0,5 \leq x < 1$	Difficult
$-0,5 \leq x < 0,5$	Moderate
$-0,5 \leq x < -1$	Easy
$x \leq -1$	Very Easy

RESULT AND DISCUSSION

Development of Aspects and Indicators for TCLbC

Chemical literacy refers to an individual's ability to understand and apply chemical knowledge based on everyday phenomena (Nada & Sari, 2021), which involves knowledge and chemical skills, whether related to social or scientific issues (Setyorini et al., 2021). Wiyarsi et al (2020) observed that chemical literacy makes students more critical and creative and helps them solve various problems in everyday life based on their knowledge.

Science literacy contexts consist of several aspects, including environmental, cultural, religious contexts, and others. Science literacy in the environmental context can be linked to Socio-Scientific Issue-based learning (Wiyarsi et al., 2021; Ke et al., 2021; Rubini et al., 2019). In the cultural context, it can be associated with Ethnoscience-based learning (Dewi et al., 2021; Rusmansyah et al., 2023; Atmojo et al., 2019), and in the religious context, it can be related to religious values (Asyhari, 2017; Asyhari, 2019; Sumirah et al., 2023). The literacy context to be applied in this study is the cultural context, specifically by integrating ethnochemistry.

The definition of chemical literacy used in this study is based on the definition and approach to science literacy from PISA (2024) and chemical literacy from Schwartz et al (2006). Table 4 presents the detailed results of the synthesis of aspects and indicators.

Tabel 4. Synthesis of chemical literacy

No.	Aspect	Indicator
1	Chemical Knowledge Concept	Refers to presenting theories to explain surrounding phenomena and to describe macroscopic phenomena by outlining processes, reactions, and energy changes in chemical reactions, as well as explaining structure and life systems.
2	Chemistry in Context	Refers to using chemical knowledge to explain phenomena in daily life, specifically local cultural phenomena.
3	Higher-Order Learning Skills	Refers to an individual's ability to analyze, identify issues, and connect them.
4	Attitude	Refers to an individual's ability to evaluate the pros/cons of an issue involving argumentation.

Development of TCLbC Instrument

The TCLbC instrument was developed through task analysis and concept analysis. Task analysis aims to analyze students' competencies in chemistry learning. The analysis was conducted using descriptive content analysis regarding the learning objectives in the Merdeka Curriculum. According to the Ministry of Education and Culture's decision on the 2024 Merdeka Curriculum, by studying chemistry, students are expected to cultivate critical thinking skills to analyze and evaluate scientific issues/phenomena in daily life and foster integrity, honesty, fairness, and responsibility; respect for the dignity of individuals, groups, communities, and global diversity. Based on task analysis, the developed test instrument will present chemistry materials relevant to real-life situations and connect scientific concepts with local phenomena.

Concept analysis aims to identify the thermochemistry concepts to be included in the chemical literacy instrument. The Merdeka curriculum teaches thermochemistry concepts in phase F, which is in grade XI. The thermochemistry concepts included are energy and enthalpy, exothermic and endothermic reactions, chemical reaction equations, types of standard enthalpy changes, calorimeters, Hess's law, and bond energy. Subsequently, the TCLbC grid was developed. Based on this grid, the chemical literacy instrument was created. The results of this development are presented in Table 5.

Tabel 5. Synthesis of chemical literacy in context

Topic	Chemistry in Context	Content Knowledge	HOLS	Indicator	Item Number
Thermochemistry in Tuak Making: Traditional Drink of the Dayak Tribe	Tuak Making: Traditional Drink of the Dayak Tribe	Concept of energy and enthalpy changes	Connecting	Students are able to connect concepts through formulas/calculations of energy and enthalpy	1c
		Difference between system and environment	Identifying	Students are able to distinguish between system and environment	1a
		Characteristics of exothermic and endothermic reactions and their energy level diagrams	Analyzing	Students are able to interpret exothermic and endothermic reactions into energy level diagrams	1b
Attitude Aspect			Argument regarding the context	Students can provide arguments about the impact of consuming tuak, the traditional drink of the Dayak tribe	1d

Topic	Chemistry in Context	Content Knowledge	HOLS	Indicator	Item Number
Thermochemistry in the Tradition of Sirih Pinang	Sirih Pinang as a main offering in Dayak society in Ketapang	Thermochemical equation	Analyzing scientific information	Students can create a thermochemical equation	2a
		Types of standard enthalpy changes	Identifying scientific information	Students can distinguish between types of standard enthalpy changes	2b
Attitude Aspect			Argument regarding the context	Students can provide arguments on the impact of chewing betel nut on health	2c
Thermochemistry in the Tradition of Nasi Hadap-Hadapan	Nasi Hadap-Hadapan, Recognizing Malay Traditional Pairs	Change in enthalpy of a chemical reaction using a calorimeter	Connecting scientific information	Students can connect concepts through formulas/calculations of reaction enthalpy using a calorimeter	3a
Attitude Aspect			Argument regarding the context	Students can provide arguments about the impact of eating sticky rice from nasi hadap-hadapan	3b
Thermochemistry in the Festival of Karbit Cannon	Karbit Cannon Festival	Change in enthalpy of a chemical reaction based on Hess's Law	Analyzing scientific information	Students can connect concepts through formulas/calculations of reaction enthalpy using Hess's Law	4a
		Change in enthalpy of a chemical reaction based on bond energy	Connecting scientific information	Students can connect concepts through formulas/calculations of reaction enthalpy using bond energy	4b
Attitude Aspect			Argument regarding the context	Students can provide arguments on the impact of Karbit cannon waste being disposed into the Kapuas River	4c

Theoretical Validity

The theoretical validity of the TCLbC instrument was assessed through expert judgment. Two expert lecturers from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, were assigned as evaluators in this study. These experts provided feedback and suggestions on the developed instrument, which the researcher subsequently used for revision. The theoretical validity process was conducted on 12 items of the TCLbC instrument, which had been formulated based on the predetermined aspects and indicators of chemical literacy. Expert feedback regarding the construction of the items included issues such as the use of inappropriate language in the questions, layout adjustments to enhance the organization of the items, and typographical errors in several terms. The researcher then addressed these suggestions. Based on the theoretical validity test results, the developed TCLbC instrument was declared valid and suitable for use. Therefore, this theoretical validity ensures that the TCLbC instrument is grounded in a strong theoretical foundation and aligns with the chemical literacy concepts intended for measurement.

Empirical Validity

Following the theoretical validity phase, the instrument underwent an empirical validity test. The empirical validity test was conducted with 70 SMA Negeri 8 Pontianak students. Based on the analysis using Winstep, the 12 items developed were valid. Data processing through Winstep is presented in Table 6.

Tabel 6. Results of empirical validity

Item Number	Outfit MNSQ	Outfit ZSTD	Pt. Mean Corr	Remarks
1a	1,19	1,24	0,09*	Valid
1b	0,90	-0,59*	0,42	Valid
1c	1,06	0,41	0,44	Valid
1d	1,16	1,08	0,25*	Valid
2a	0,77	-1,29*	0,77	Valid
2b	1,06	0,42	0,41	Valid
2c	0,95	-0,29*	0,46	Valid
3a	0,90	-0,43*	0,50	Valid
3b	0,88	-0,70*	0,58	Valid
4a	0,91	-0,31*	0,41	Valid
4b	0,98	0,02	0,22*	Valid
4c	1,46	1,70	0,28*	Valid

**Out of criteria*

Based on the analysis using Winsteps, all 12 developed items were valid. The data processing results through Winsteps show the values of Outfit MNSQ, Outfit ZSTD, and Pt. Mean Corr for each item was then compared with the Rasch Model validity criteria. Although some values did not meet one of the criteria individually (marked with '*'), overall, all 12 chemistry literacy items developed were declared valid based on the established criteria.

Reliability Testing

Reliability testing assesses the extent to which a measurement tool can be trusted or relied upon. The reliability results for the TCLbC instrument show a Cronbach's alpha value of 0.56 (adequate), person reliability of 0.68 (adequate), and item reliability of 0.95 (very high).

These reliability results indicate that the TCLbC instrument has several strengths, even though Cronbach's alpha and person reliability values fall under the "adequate" category. The very high item reliability value, which is 0.95 (classified as "very high"), indicates that the items in this instrument are very consistent in measuring the same construct, namely chemical literacy. This means that each item tends to provide similar results when re-administered to the same group of students (assuming no changes in student abilities). Consistency at the item level strongly indicates that the items are well-designed to measure the targeted aspects of chemical literacy.

Meanwhile, Cronbach's alpha value of 0.56 and person reliability value of 0.68, both classified as "adequate", should be considered within the context of instrument development. Cronbach's alpha is a measure of the overall internal consistency of the instrument. An "adequate" value may be caused by factors such as the relatively small number of items (12 items) or variation in student responses to items measuring different aspects of chemical literacy. Person reliability reflects the consistency of answers among students. An "adequate" value in person reliability may indicate significant variability in chemical literacy levels among the students tested.

Although the overall reliability of the instrument and person reliability do not fall under higher categories, the "very high" item reliability provides confidence that each item individually is a reliable measure of the targeted aspects of chemical literacy. In the context of instrument development, this result suggests that the items developed are of good quality when measuring the desired construct. A reliable test will consistently provide reliable results (Alti et al., 2022).

Difficulty Level

The difficulty level of an item indicates the likelihood of how many respondents can correctly answer an item. The results of the are presented in Table 7.

Tabel 7. Results of difficulty level analysis

Item Number	Measure logit	Category
4a	.63	Difficult
4b	.55	Difficult
4c	.49	Moderate
3a	.29	Moderate
3b	.10	Moderate

1d	-.12	Moderate
2b	-.16	Moderate
1a	-.19	Moderate
2c	-.29	Moderate
1b	-.34	Moderate
1c	-.43	Moderate
2a	-.55	Easy

The distribution of item difficulty levels in a varied manner is an indicator of good instrument quality. A high-quality test should not consist solely of items that are too easy or difficult but rather should encompass a broad range of difficulty levels to assess students' abilities across different levels of understanding. Items with an easy difficulty level allow students with basic understanding to answer correctly, items with moderate difficulty measure deeper conceptual comprehension, and items with high difficulty can identify students with excellent understanding and high application skills. Ideally, a test should use items with a balanced difficulty distribution, namely 25% difficult, 50% moderate, and 25% easy items (Bano & Njoeroemana, 2022).

Based on Table 7, the TCLbC instrument consists of 2 difficult items, 9 moderate items, and 1 easy item. An item categorized as difficult was identified in question item 4a, which instructed students to calculate bond energy. This item was classified as difficult because it required students to perform direct calculations and analyze and interpret bond energy data to determine the molecular structure of the compounds involved. To solve this question, students were expected to recall basic concepts and analyze the molecular structures of the reactants and products, identify the broken and formed bonds, and accurately apply bond energy data. This process demanded a strong conceptual understanding of the relationship between molecular structure and bond energy and high-level analytical skills to integrate various pieces of chemical information.

Meanwhile, an item categorized as moderate was found in question item 3a, which instructed students to calculate the enthalpy change based on calorimetric experiment results. This item was considered moderately complex because students only needed to substitute values into the heat calculation formula without the need to analyze molecular structures or interpret complex data. Nevertheless, solving this question required precision in processing temperature changes, substance mass, and specific heat capacity data. As the solution was procedural and involved a relatively low level of analysis, the item fulfilled the characteristics of a question with moderate difficulty.

Lastly, an item categorized as easy was identified in question item 2a, which instructed students to write a thermochemical equation. This item was classified as easy because it only required students to understand the basic concept of the relationship between heat and the sign of enthalpy change in a chemical reaction. The solution was straightforward and did not involve advanced analysis, data interpretation, or complex calculations. Students needed to recall that endothermic reactions have a positive enthalpy value and integrate this information into an appropriate chemical equation. Due to its low cognitive demand and the familiar context within classroom instruction, this item met the criteria for an easy-level question..

CONCLUSION

The theoretical validity of the TCLbC instrument was assessed through expert judgment. Two expert lecturers from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, were assigned as evaluators in this study. These experts provided feedback and suggestions on the developed instrument, which the researcher subsequently used for revision. The theoretical validity process was conducted on 12 items of the TCLbC instrument, which had been formulated based on the predetermined aspects and indicators of chemical literacy. Expert feedback regarding the construction of the items included issues such as the use of inappropriate language in the questions, layout adjustments to enhance the organization of the items, and typographical errors in several terms. The researcher then addressed these suggestions. The developed TCLbC instrument was declared valid and suitable based on the theoretical validity test results. Therefore, this theoretical validity ensures that the TCLbC instrument is grounded in a strong theoretical foundation and aligns with the chemical literacy concepts intended for measurement.

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