



Contents lists available at [Journal IICET](#)  
**Jurnal EDUCATIO (Jurnal Pendidikan Indonesia)**  
ISSN: 2476-9886 (Print) ISSN: 2477-0302 (Electronic)  
Journal homepage: <https://jurnal.iicet.org/index.php/jppi>



## Needs analysis of an integrated assessment instrument of chemical literacy and critical thinking among senior high school students and chemistry teachers

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### Article Info

#### Article history:

Received Sep 13<sup>th</sup>, 2025  
Revised Sep 21<sup>th</sup>, 2025  
Accepted Oct 31<sup>th</sup>, 2025

#### Keyword:

Integrated Assessment Test  
Chemical Literacy  
Critical Thinking  
Chemistry Teachers  
High School Students

### ABSTRACT

Chemical literacy and critical thinking are essential skills in today's science education, as they enable individuals to understand how chemistry explains real-world phenomena. However, current school assessments do not measure both skills simultaneously. This study aims to analyse and provide information on teachers' and students' perspectives on the need for assessments that simultaneously measure students' chemical literacy and critical thinking. This research used a qualitative descriptive method. Data were obtained through a systematic literature review, including identification, screening, eligibility, and inclusion, as well as through empirical fieldwork via interviews and questionnaires. Empirical interview data were analysed using thematic analysis, and questionnaire data were analysed using narrative analysis. This study involved three chemistry teachers and 63 students studying chemistry. The results indicated that the development of integrated assessment tests could address the demands of 21st-century education. Teachers generally recognised the importance of chemical literacy and critical thinking in learning, but there were still limitations in utilising appropriate assessment tests. Many students still struggled to relate chemistry to everyday life, so their critical thinking skills for addressing chemical problems in real contexts were not practised through existing test items. These findings highlighted the need to develop an integrated assessment of chemical literacy and critical thinking that not only measures students' understanding of chemistry concepts but also develops analytical skills to analyse and apply chemical knowledge in real-life situations.



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## Introduction

The rapid development of science and technology, which is becoming increasingly complex and dynamic, will affect the sustainability of human life. Therefore, humans play a crucial role in wisely utilising these advancements and fostering scientific literacy to make informed decisions in the face of challenges or problems, thereby minimising negative impacts on the environment and society. Thus, scientific literacy becomes an essential skill for individuals to possess (Marfuatun, Nahadi, Yuliani, & Hernani, 2024; Muntholib et al., 2020). In modern science education, scientific literacy is conceptualised as a primary goal of science teaching (Muntholib et al., 2020). Contemporary science education no longer merely aims to produce individuals who

become scientists but also to develop scientifically literate, intelligent, and critical individuals who are prepared to face global challenges (such as environmental pollution, climate and energy issues, health, and others) (Nasor, Lutfi, & Prahani, 2023; Vogelzang, Admiraal, & Van Driel, 2020). Through science education, scientific literacy can serve as an essential step in promoting the advancement of science, technology, and economic sustainability (Schellekens et al., 2021).

According to PISA (Programme for International Student Assessment), scientific literacy is the ability to understand scientific concepts and engage with science-related issues critically and reflectively as a citizen (OECD, 2025). In the context of chemistry, scientific literacy serves as the fundamental basis for developing chemical literacy. Chemical literacy is a subset of scientific literacy; by definition, it refers to individual's understanding of chemistry, which includes core concepts in basic chemistry such as elements, symbols, the properties of chemical laws and theories, general applications of chemistry in everyday life, as well as knowledge of the roles chemists play in academic, industrial, and social contexts (Aryani, Susilowati, & Utami, 2022; Kohen, Herscovitz, & Dori, 2020). Chemical literacy aims to equip individuals to become chemically literate people so that they can face problems in everyday life related to chemistry with confidence, have better job opportunities, and strengthen the quality of society to be more aware, informed, and able to make decisions so that they can later support the country's economic progress (Marfuatun et al., 2024; Osborne, 2023; Ploj Virtič, 2022).

Chemical literacy are related to critical thinking skills. Several studies also suggest that students' chemical literacy is not solely due to lack of conceptual understanding but also to lack of critical thinking skills (Hu & Bi, 2025). Critical thinking is the ability to think logically, reflectively, and independently to make decisions about what to believe or do (Muhammad Jamil, Dr. Yaar Muhammad, & Dr. Naima Qureshi, 2021; Seang, 2021). Critical thinking is a skill that helps students effectively solve and explain real-life problems (Halpern & Dunn, 2021; Hu & Bi, 2025). Nowadays, information is easily disseminated and anyone can quickly receive it, including students who are constantly exposed to various types of information. In conditions like these, critical thinking is a very important skill and students need to have it (Hu & Bi, 2025). Critical thinking is not an inherent skill, but rather one that can be honed and improved through the progression of education (Halpern & Dunn, 2021; Seang, 2021).

Given the importance of chemical literacy and critical thinking in chemistry learning, teachers need to be responsible for developing test assessment that can be used to simultaneously measure students' chemical literacy and critical thinking skills. Assessment is the process of collecting data to determine the extent to which students achieve the expected learning outcomes (Levy-Feldman, 2025; Shi, Wang, Mitchell-Jones, & Stains, 2024). In addition to measuring student learning outcomes, assessment is a process intentionally designed to understand students' learning conditions. Educators can understand the difficulties students experience in grasping concepts and identify ways to improve their learning (Ismail, Rahul, Patra, & Rezvani, 2022; Shi et al., 2024). Additionally, the results of this student assessment can serve as a basis for the government to formulate educational policies, including curriculum design, academic program development, and school management (Levy-Feldman, 2025). Assessment has a significant influence on students' learning processes. Assessment can guide what students consider essential during learning, shape their understanding of the material, and influence their level of engagement in the learning process (Schellekens et al., 2021). If existing assessments emphasize memorization, students will tend to focus on memorizing facts. However, if assessment emphasize deeper understanding, this will encourage a deeper understanding of chemistry material (Djaen, Rahayu, Yahmin, & Muntholib, 2021; Schellekens et al., 2021). Assessment that align with expected learning outcomes help foster lifelong learning. In line with this, assessment must consistently align with learning objectives (Levy-Feldman, 2025). The learning objectives in current science education are to develop students' thinking skills to solve everyday problems (scientific/chemical literacy) and to foster critical thinking skills. However, current assessment tend to rely on memorization, which is inconsistent with the goals of science material, and application of chemical concepts in real life, which is now referred to as scientific literacy (Muhammad Jamil et al., 2021; Nur Khayati, 2021; Shi et al., 2024).

Based on research by Masruroh et al. (2022), on the use of chemistry questions in one school in Kebumen, the results showed that the chemistry questions were dominated by the LOTS (Low Order Thinking Skills) cognitive level (65%), including cognitive levels C2 and C3, with conceptual knowledge. The lack of HOTS (High Order Thinking Skills) cognitive levels, including C4, C5, and C6. In addition, teachers can make their lessons more interesting and challenging by adding images, graphs, and tables, and by making them relevant to everyday life. The goal is for students to analyze the conditions and relationship among chemistry concepts and phenomena in everyday life, enabling them to develop solutions to problems grounded in these concepts (Masruroh, VH Susanti, & Mulyani, 2022). Febriyanti and Endang (2025) also stated that the concept of critical thinking has been understood by chemistry teachers and stated that it is necessary to design chemistry questions

with a high level and context based aspects (chemical literacy), one of which is time, making teachers as educators have not fully implemented chemical literacy and critical thinking in questions (Febriyanti & Widjajanti, 2023) Research by Bortnik et al. (2021), found that context based assessment is necessary because teachers' assessments remain traditional, measuring theoretical knowledge and memorization rather than context. These findings show that the assessment used does not foster critical thinking or enhance students' chemical literacy. The authors developed a context based assessment, and the results of the experiment showed that students who received treatment focused on context based chemistry problems achieved higher learning outcomes. In contrast, students in the control group who did not receive treatment to work on context based chemistry problems did not show an increase in learning outcomes (Bortnik, Stozhko, & Pervukhina, 2021).

Until now, many studies have developed assessment instruments to assess chemical literacy and critical thinking separately, but few have developed instruments to measure students' chemical literacy and critical thinking simultaneously. Based on research conducted by Ariefiani & Laksono (2024), who developed an assessment instrument that can measure chemical literacy and critical thinking of students on the material of reaction rates, said that measuring more than one ability or skill namely in this case chemical literacy and critical thinking, can provide significant results on student learning outcomes, namely a higher level of knowledge and stronger mastery of knowledge. However, the study did not test the practicality of the assessment instrument when implemented, did not present the results or analyse the data on students' chemical literacy and critical thinking scores, and did not guide how to assess and interpret the assessment results (Ariefiani & Laksono, 2024; Listiani, Susilo, & Sueb, 2022; Sjöström, Yavuzkaya, Guerrero, & Eilks, 2024). Research conducted by Ware et al. (2024) also discussed the development of an integrated assessment of chemical literacy and HOTS, incorporating ethnoscience from the Sikka region, on acid based material. The study found that the HOTS literacy assessment instrument met validity standards and served as an effective evaluation tool for acid-base material/ the readability analysis was categorized as very good by students and educators. In general, the instrument passed the validity and readability tests, which were predominantly good, so it can be applied to measure learning outcomes in acid base material. However, the study has a limitation; it did not include a dissemination stage. As a result, the authors did not disseminate the assessment in a classroom setting and did not present measurement data on chemical literacy and critical thinking (Klaudius Ware, Paulina Nelce Mole, & Yohanita Nirmalasari, 2024).

Considering the importance of chemical literacy and critical thinking in chemistry learning, the study of combining assessment instruments that can measure these constructs is a research endeavor that can offer a new approach and overcome the limitations of previous research, which still separates the measurement of chemical literacy and critical thinking. This study aim to obtain a comprehensive picture of the need and suitability for developing assessment instruments for chemical literacy and critical thinking in chemistry learning in. More specifically, this question research are: 1) How are the development and characteristics of chemical literacy and critical thinking assessment instruments in previous research? 2) What are the needs of teachers and students for assessment instruments that can measure chemical literacy and critical thinking skills?. This study aims to provide initial information to future researchers who are interested in developing assessment instruments that can measure chemical literacy and critical thinking simultaneously, to chemistry teachers to provide information on improving assessment instruments for 21st century education, and students can have the opportunity to improve and enhance chemical literacy and critical thinking skills through the developed assessment instruments, as well as for policy makers who can utilize the results of this study as input for curriculum development.

## Method

Based on the research objectives, then this research design uses a qualitative approach. This study employed a qualitative descriptive method. Qualitative descriptive method research dipilih karena is an approach that aims to gain an in-depth understanding of a problem or phenomenon, providing a comprehensive overview of the data obtained. Thus, the findings can explain the characteristics and patterns emerging from the studied populations (Ayton, Tsindos, & Berkovic, 2023). The context of this research is to enable in-depth exploration of teacher and student perceptions and provide a comprehensive picture of assessment needs

This study was conducted during the odd semester of the 2024/2025 school year at one of the state High School in Subang Regency, West Java Province, Indonesia, involving 63 students and 3 chemistry teachers. The teachers involved have >15 years of teaching experience, and the students involved are studying chemistry material. The participant was selected using convenience sampling. Convenience sampling is a sampling technique based on the ease and availability of participants for the research (Ayton et al., 2023). Data collection technique was conducted through a systematic literature review of journal articles and the empirical field study was conducted through interviews and the distribution of questionnaires.

A systematic literature review is a review method that follows standard rules in identifying, assessing, collecting, and critically synthesising research articles relevant to the topic under study. A systematic literature review is employed in this study to present comprehensive evidence on the topic being examined, to create a strong theoretical foundation or framework, and to build a conceptual model for future research based on organized findings. The literature review in this study was conducted using a descriptive review approach, namely a scoping review, which aims to map the extent to which a topic has been researched (Xiao & Watson, 2019). In this study, we used the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines for a systematic literature review. The PRISMA literature review is clear and structured throughout. The steps of the PRISMA method include: Identification, Screening, Eligibility, and Included (Yue, Yuxuan, & Surip, 2025). More specifically, the literature review steps in this study are as follows.

### Identification

This stage involves identifying (finding and considering) articles to search for based on appropriate keywords. Keywords serve to facilitate article searches and improve article accuracy. The keywords used to search for articles for this study are: "scientific literacy", "chemical literacy", "critical thinking", "assessment instrument development", and "Integrated assessment instrument". Articles search through the Science Direct, ERIC, and Google Scholar databases. The presence of articles in these three databases indicates international research, allowing us to understand global research trends, such as what is being focused on in the field of education. Searching on Google Scholar is also intended to expand the scope of the literature, including accredited national journals. According to Xiao and Watson (2019), the literature search must be comprehensive to minimize bias, and the literature review conducted is a thorough or scoping review, so the quality of the research is not the primary concern (Xiao & Watson, 2019). A keyword search yielded 111 journal articles. These journal articles will then undergo a screening process for analysis.

### Screening

This stage involves screening the articles obtained during the identification process. 111 journal articles were then screened according to the inclusion and exclusion criteria. The screening stage aims to ensure that the articles selected for the final analysis are genuinely relevant to the research topic. In this phase, the criteria for article selection for the review were also determined, as further explained in the available.

Table 1. Article Criteria

Category	Inclusion	Exclusion
Year of publication	2015-2025	< 2015
Publication types	Journal articles	Literature review article
Language	English and Bahasa Indonesia	Bahasa selain bahasa inggris dan bahasa indonesia
Focused of findings	The article discusses the development of chemical literacy assessment instruments, the development of critical thinking assessment instruments, and integrated assessment instruments for chemical literacy and critical thinking.	Articles that do not discuss the development of chemical literacy assessment instruments, the development of critical thinking assessment instruments, and integrated assessment instruments for chemical literacy and critical thinking.
Types of findings	Empirical and RnD study (Research and Development)	Literature review, essay, opinion

Based on the screening results, 84 journal articles were identified as not meeting the requirements and would be excluded, while 27 journal articles would proceed to the Eligibility stage.

### Eligibility

This stage is the second screening stage. It aims to re-ensure that articles are relevant to the research objectives and provide essential and meaningful contributions (Hamzah, Hamzah, & Zulkifli, 2022; Yue et al., 2025). The article's eligibility review process involves assessing the abstract, methodology, results, and discussion. In this process, 14 of the 27 journal articles were analyzed further because the research met the inclusion criteria, and the results and discussion were helpful in further analysis and debate.

## Inlcuded

After going through a series of stages in reviewing research articles, 14 articles were selected for in-depth analysis, which is expected to serve as the basis for this research synthesis. These 14 articles will then undergo data analysis and synthesis.

The empirical field study was conducted through interviews and the distribution of questionnaires. The data were then analysed descriptively to describe or present the collected data in the form of percentages, averages, or other types of descriptive statistics. This facilities interpretation of the results, which can then used to explain patterns and characteristics without generalising the findings (Rahmi., Kustati, & Hadeli, 2022). The research instruments used were interview guidelines and questionnaires. An interview guideline outlines the questions researchers ask during the interview process. Interviews are a data collection technique that involves gathering data from primary sources to provide in-depth information aimed to identify, observe, and explore existing problems by understanding them through the respondents (Ayton et al., 2023; Djiwandono & Yulianto, 2023). Interviews are often considered an appropriate data collection method and are recommended for use in the initial stages of new research (Taherdoost, 2022). The interviews used in this study were semi-structured. The interview lasted approximately 30 minutes, and during it, the author recorded it and noted several essential points. A questionnaire is a research instrument containing several statements or questions; in this study, the questionnaire contained statements. Based on the statements/questions in the questionnaire, the questionnaire used in this study was a closed-ended one, in which the statements already contain answers, allowing students to choose the option that aligns with their opinions or experiences (Taherdoost, 2021). The questionnaire was distributed to two chemistry classes. The researcher was directly involved in distributing the questionnaire, which addressed the need for an assessment instrument to measure chemical literacy and critical thinking. These classes were selected based on participants' availability to participate in the study.

Empirical data were analyzed using thematic analysis. Thematic analysis (Braun and Clark, 2006) is a qualitative data analysis that aims to identify and analyze data to find patterns or themes. These patterns or themes are generated from the researcher's interpretation (Kable, Wang, Shi, & Stains, 2025). The steps in thematic analysis are: (1) familiarization or introduction of data, which is the stage where researchers need to focus on understanding and interpreting the data by transcribing and rereading the data. (2) Generating codes, which is the stage where essential data are coded. (3) Searching for and building themes, this stage is carried out by compiling and combining codes that are similar or similar in nature (seeing the relationship patterns of each code) to form categories and then generating themes. (4) Revising themes, which is the stage to recheck the themes. (5) Determining and naming the themes that have been formed. (6) Making reports (Kable et al., 2025). To ensure the validity of data regarding the need for an integrated assessment instrument for chemical literacy and critical thinking, triangulation was conducted. The triangulation used was source triangulation, conducted during in-depth interviews with three chemistry teachers and through questionnaires administered to more than one student. The purpose of triangulation was to provide researchers with a deeper understanding of the findings (Medica et al., 2020).

## Results and Discussions

### Needs Analysis Results based on Literature Review

To establish a theoretical framework and build a conceptual model for this research, a review of relevant articles was conducted. The results of the systematic article review of 14 journal articles are presented in the table below.

Table 2. Articles in Systematic Literature Review

Author's Name, Year	Article Title	Purpose	Findings
Chemical Literacy (5 articles)			
(Eliza et al., 2021)	Development of Chemical Literacy Test Items on Colloidal System Material for 11th Grade Science (IPA) High School/MA	To develop an instrument capable of measuring students' chemical literacy levels spesifically on the topic of colloidal systems	A test instrument designed to measure chemical literacy on colloidal systems consists of 12 essay questions. The quality test of the assessment instrument involved content validity by five experts, and the results showed that all items met the established assessment criteria. Reliability was assessed using the Rasch model, with a strata value of 3.1, indicating that the examiner's assessment is

Author's Name, Year	Article Title	Purpose	Findings
(Setyorini, Yamtinah, Mahardiani, & Saputro, 2021)	A Rasch Analysis of Item Quality of the Chemical Literacy Assessment for Investigating Student's Chemical Literacy on Chemical Rate Concepts	To examine the validity of the assessment items and measure students' understanding of chemical literacy in the context of reaction rate material.	reliable. The reliability value obtained was 0.8, which falls within the good category. The study results indicate that the chemical literacy assessment, comprising 14 multiple choice items, is both valid and reliable for evaluating students' chemical literacy. Nevertheless, the findings also highlight that students' chemical literacy remains in need of improvement.
(Muntholib et al., 2020)	Chemical Literacy : Performance of First Year Students on Chemical Kinetics	To develop and validate a multiple choice instrument aimed at measuring chemical literacy in the area of chemical kinetics, and implement the instrument with students to evaluate their chemical literacy performance on the topic	The developed chemical literacy test instrument consisted of 50 multiple choice questions, referred to as the MC-CLTI (Multiple Choice Chemical Literacy Test Instrument) on the topic of chemical kinetics. After content validation by experts and revisions, the number of items was reduced to 40. Empirical validity testing showed that 30 items were valid and 10 were invalid. The reliability score (Cronbach's Alpha) was, 774, indicating the instrument is reliable. Students' chemical literacy scores ranged from 3,00 to 93,33, with an average of 63,24, indicating a good level of chemical literacy. Performance in the competency aspect (analysis and reasoning) was higher than in the knowledge aspect.
(Ardyansyah, Rahayu*, Munzil, Yahmin, & Alsulami, 2025)	Developing an Instrument to Assess Chemical Literacy for Prospective Chemistry Teachers	To develop and validate an assessment instrument to measure chemical literacy in general chemistry courses, to identify existing gaps and contribute to the improvement of pedagogical practices.	The chemical literacy test instrument developed is a multiple choice test consisting of 50 items, based on PISA 2025 framework, and only use competency aspect. Validity test using Aiken's V, which yielded a score of 0,6675 (relatively high) and the reliability score obtained was 0,818 (reliable). After revision based on expert input and statistical analysis, 23 items were deemed suitable for evaluating the chemical literacy of chemistry students.
(Coppi, Fialho, & Cid, 2023)	Developing a Scientific Literacy Assessment Instrument for Portuguese 3rd Cycle Students	Designing and validating the ALCE (Avaliacao da Literacia Cientifica Essencial) instrument to assess students' scientific literacy skills	The ALCE instrument was developed to assess the scientific literacy skills of students at the end of the 3rd cycle of basic education in Portugal. The test instrument uses a three-option multiple choice format (true, false, and don't know). Based on the validity results, it was found that ALCE can be used for decision making regarding students' scientific literacy, and 64,14% were categorized as generally literate.
(Danczak, Thompson, & Overton, 2020)	Development and validation of an instrument to	Developing and evaluating a context specific DOT test to determine whether the	Critical Thinking (4 articles) This study demonstrates that the critical thinking assessment in the context of chemistry (DOT V3) exhibits strong criterion validity, as evidenced by differences in scores

Author's Name, Year	Article Title	Purpose	Findings
	measure undergraduate chemistry students' critical thinking skills	DOT test can measure the critical thinking skills of undergraduated chemistry students.	across various educational levels. A qualitative finding during the test development revealed that assessing critical thinking skills independently of context is challenging, as students tend to consistently rely on their prior knowledge. This supports the view that critical thinking cannot be entirely separated from context.
(Nurfatihah, Nahadi, & Firman, 2021)	Development of Chemistry Tests for Students' on Reaction Rate Subject Matter Based on Critical Thinking Skills using Framework DOT Test	To develop a valid and reliable assessment aimed at evaluating the critical thinking abilities of 11th-grade high school students on reaction rate topics, utilizing the DOT (Danzack Overton Thompson) test framework	This study developed a chemistry test based in the DOT framework to measure students' critical thinking skills on the topic of reaction rates. A total of 30 items were constructed based on 20 indicators and the DOT version of essential thinkig indicators. The validation outcomes indicated that 29 test items met the validity criteria, demonstrated strong validity scores, and were appropriate for assessing students' critical thinking abilites within the field of chemistry.
(Hasan, Auliah, & Herawati, 2020)	Pengembangan Instrumen Penilaian Kemampuan Berpikir Kritis Siswa SMA	To develop instruments that can train and accustom students to critical thinking, so that students become accustomed to practicing critical thinking in solving problems.	The critical thinking assessment instrument was developed with a focus on stoichiometry. This instrument included 11 descriptive questions. The critical thinking indicators used were those from Ennis (1993), but they did not specify the specific indicators. To ensure high instrument quality, the assessment instrument in this study included a validity test (content and construct), with a validity coefficient of 91.66%. The instrument's reliability was 0.894 (Cronbach's alpha), which is categorized as high. The item difficulty level was moderate, and the item's discriminating power was 0.47, indicating good discriminating power.
(Rashel & Kinya, 2021)	Development and Validation of a Test to Measure the Secondary Students' Critical Thinking Skills: A focus on Environmental Education in Bangladesh	Develop and validate question isnruments that can measure students' critical thinking skills in environmental education material	The critical thinking test instrument consists of 27 multiple choice questions based on 3 indicators of critical thinking namely Drawing Conclusion, Inference Making, and Identifying Bias, which were finalized after piloting testing and expert review. The test found to be valid (significance < 0,005) and reliable (coefficient 0,7756). The items had moderate difficulty, making the test suitable for assessing secondary students' critical thinking. However, it does not fully cover all dimensions of critical thinking.
Integrated Chemical Literacy and Critical Thinking (5 articles)			
(Sadhu et al., 2019)	Exploring and Comparing Content Validity and Assumptions of Modern Theory of an Integrated Assessment : Critical Thinking-	To explore and compare the evidence of content validity and the assumptions of modern theory in integrated assessments used to measure students' critical thinking and chemical literacy skills	The form of the develoed questions consists of 37 open multiple-choice questions that are valid and feasible for measuring critical thinking and chemical literacy on chemical equilibrium, with Aiken's $V > 0,83$ catagorized a high level of suitability. Based on the assumptions of modern theory (IRT), the instrument assessment is construct valid and can objectively and consistently measure these skills.

Author's Name, Year	Article Title	Purpose	Findings
(Ariefiani & Laksono, 2024)	Chemical Literacy Studies Development of An Integrated Assessment Instrument to Measure Students' Critical Thinking and Chemical Literacy Skills for Rate of Reaction Topic	Developing an integrated assessment instrument that can measure students' critical thinking skills and chemical literacy, especially in reaction rate materials	The integrated assessment instrument developed consists of ten essay questions on the topic of chemical reaction rates, with content validity confirmed by six experts (Aiken's $V = 0,78$ ). Rasch analysis met all construct validity assumptions and reliability testing showed high reliability for both items and participants, making it valid and reliable for measuring critical thinking and chemical literacy.
(Simamora, Astalini, & Darmaji, 2022)	Validitas dan Keterbacaan Integrated Assesment Literasi Kimia dan HOTS Bermuatan Etnosains Daerah Sikka pada Materi Asam Basa	To test the validity and reliability of the integrated assessment of chemical literacy and HOTS containing Sikka regional ethnoscience on acid-base material	The HOTS literacy assessment developed is in the form of essay questions. The validity testing results indicate that the HOTS literacy assessment meets valid standards, with a score greater than 8,0, indicating that the test has high validity. The reliability analysis of hte questions in the HOTS literacy assessment is catagorised as excellent by both students and teachers. Based on the validity and reliability tests, the evaluation can be used to measure learning achievement in acid-base material.
(Satya Sadhu & Laksono, 2018)	Development and Validation of an Integrated Assessment for Measuring Critical Thinking and Chemical Literacy in Chemical Equilibrium	To develop and validate an integrated assessment instrument to evaluate critical thinking skills and chemical literacy on the topic of chemical equilibrium for 11th-grade high school.	This integrated assessment instrument for critical thinking and chemical literacy produces thirteen integrated skills related to the topic of chemical equilibrium. It consists of 29 open ended multiple choice questions and demonstrate high validity and reliability (0,85), making it suitable for assessing these skills effectively.
(Wigati, Noer, & Anwar, 2023)	Validity of instruments for assessment of scientific literacy and critical thinking of students based on multiple intelligence in acid-base material	Aims to develop an assessment instrument to assess students' scientific literacy and critical thinking on acid-base material.	The assessment instrument, developed to measure students' chemical literacy and critical thinking, consists of 16 questions organized into 4 indicators. However, the chemical literacy and critical thinking indicators used were not explained by the researcher. This research has only reached the initial product development stage and has not yet progressed to field trials, dissemination, or implementation. The quality test of the product assessment instrument developed in the initial stage was conducted using content validity, assessed by three experts. The result: the assessment instrument was deemed valid in material, constructive, linguistic, and creative terms, making it suitable for measuring students' critical thinking abilities, especially in acid-base material.

Research on the development of assessment instruments for chemical literacy and critical thinking has been extensively researched and remains a frequently discussed topic today. Based on a literature review, in research

on the development of chemical literacy assessments conducted by (Eliza & Yusmaita, 2021; Setyorini et al., 2021; Muntholib et al., 2020; Ardyansyah, et al., 2025; Coppi et al., 2023), the chemical literacy assessments developed focused on a single selected topic. This could be an opportunity to develop assessment instruments that cover several chemistry topics to yield results that describe overall chemical literacy abilities. Several articles discussing the development of chemical literacy assessments show that the assessments developed to date have not yet implemented all four aspects of chemical literacy, as in the study by Setyorini et al. (2021), which used content and context. Furthermore, in the survey by Eliza & Yusmaita (2021), they developed a chemical literacy assessment for colloids based on four aspects: content, context, higher-order learning skills, and attitudes. However, the higher-order learning aspects of chemical literacy were not explained in terms of their application to the questions. Therefore, the developed questions were considered context-based and did not train students in higher-order thinking skills. Instrument quality testing was mainly conducted only on validity and reliability tests. The overall results of students' chemical literacy measurements still need improvement. Meanwhile, critical thinking assessment instruments, such as those developed by Danzack et al. (2020), Nurfatihah et al. (2021), and Rashel & Kinya (2021), demonstrate the importance of contextual critical thinking being assessed still do not cover at all dimensions of critical thinking and the contextual emphasis in the questions is not yet complete, as shown in the example questions in Nurfatihah et al., (2021). A student with a strong critical thinking skills can act as an environmental leader in solving existing problems and preventing future threats (Danczak et al., 2020; Nurfatihah et al., 2021; Rashel & Kinya, 2021).

A review of several recent studies integrating chemical literacy and critical thinking (Ariefiani & Laksono, 2024; Sadhu & Laksono, 2018; Sadhu et al., 2019; Simamora et al., 2022; Wigatiet al., 2023) shows that the development of integrated assessment instruments can meet the demands of 21st-century education. Integrated assessment instruments for chemical literacy and critical thinking are presented as measurement tools that assess students' skills in these areas. Measuring both skills simultaneously can provide more comprehensive measurement results, making them more effective and efficient (Satya Sadhu & Laksono, 2018; Simamora et al., 2022). Both skills (chemical literacy and critical thinking) are complementary and interrelated; in addition, they are very much needed in the 21st century (Afnan, Budiyanto, Izzur, & Aulia, 2023; García-carmona, 2025). When applied to questions, chemical literacy emphasizes the content of chemistry and its role in everyday life. In contrast, critical thinking emphasizes higher-order thinking skills, as noted by Ariefiani & Laksono (2024), including identifying problems, building arguments, analyzing problems, evaluating problems, and drawing conclusions. Through this assessment instrument, teachers can see how students' understanding of chemical concepts is reflected in their problem-solving using critical thinking skills. The results of measuring chemical literacy and students' critical thinking can be produced, showing that students understand the concept but cannot answer the question because it requires advanced thinking skills or higher-order thinking. Thus, based on the measurement results, teachers can improve the learning system and develop appropriate learning strategies (Ariefiani & Laksono, 2024; S. Sadhu, Ad'hiya, & Laksono, 2019; Simamora et al., 2022; Wigati et al., 2023).

### **Needs Analysis Results based on Empirical Field Studies**

The discussion of the analysis results will be divided into two sections: the needs for chemical literacy and critical thinking assessment, as perceived by teachers, and the needs of chemical literacy and critical thinking assessment, as perceived by students.

#### **The Need for Chemical Literacy and Critical Thinking Assessments According to Teachers**

The interviews conducted with chemistry teachers consisted of 10 questions. The results of the interviews from the three teachers produced 31 codes, which were then conceptualized into 6 dan memuat tema yaitu . The following is a detailed summary of the results of the interviews with chemistry teachers.

When something is to be applied and studied, the first thing to consider is understanding the topic's conceptual definition. In the context of this research, it is necessary to examine teachers' understanding of each concept, including chemical literacy and critical thinking, so that they can develop and evaluate students' chemical literacy and critical thinking skills (Febriyanti & Widjajanti, 2023). Based on the interview results, teachers' understanding of the definition or concept of chemical literacy differed slightly but shared the same core meaning. Respondent 1 explained, "Chemical literacy is knowledge of chemistry acquired through reading from various sources, including printed books, digital books, YouTube, Google, and other media". In contrast, respondent 2 explained, " Literacy means reading, not necessarily from books, can read from the media, even read the environment. Chemical literacy means that students can read the products that exist in everyday life related to chemistry". While respondent 3 explained that "Chemical literacy is the habit of children solving chemical problems based on the data and discourse in detail". The teachers's answer is by the definition of chemical literacy according to Thummatong & Thathong (2018) and Dori et al (2018), chemical literacy is a person's ability to understand and apply chemistry in everyday life, as well as understand issues or problems

related to chemistry (Dori, Avargil, Kohen, & Saar, 2018; Thummathong & Thathong, 2018). This indicates that teachers already possess a knowledge and understanding of chemical literacy and its importance in the learning process.

Table 3. Summary of interview results

Theme	Categories	Code
Conditions and perspectives of teachers on the need for integrated assessment instruments for chemical literacy and critical thinking	Teachers' understanding of chemical literacy and critical thinking	<ul style="list-style-type: none"> <li>• Acquiring chemical knowledge through reading</li> <li>• Ability to relate chemical knowledge to everyday life</li> <li>• Ability to express and analyse information etc ...</li> </ul>
	Application of chemical literacy and critical thinking assessment	<ul style="list-style-type: none"> <li>• The assessment has not yet implemented chemical literacy</li> <li>• The chemical literacy assessment has not been fully implemented</li> <li>• The cognitive level of the questions is at the basic cognitive level (C1-C3) etc ...</li> </ul>
	Application of chemical literacy and critical thinking methods	<ul style="list-style-type: none"> <li>• Chemical literacy-based learning methods</li> <li>• Diverse learning methods</li> <li>• Learning methods do not fully implement critical thinking etc ...</li> </ul>
	Question format used	<ul style="list-style-type: none"> <li>• Multiple-choice and essay-based question formats</li> <li>• Essay-based and varied question formats</li> </ul>
	Advantages of integrated assessment of chemical literacy and critical thinking	<ul style="list-style-type: none"> <li>• Helps develop potential</li> <li>• Able to apply knowledge in everyday life</li> <li>• Helps understand chemistry concepts etc ...</li> </ul>
The challenge of integrated assessment of chemical literacy and critical thinking	<ul style="list-style-type: none"> <li>• Variation in student abilities is a challenge</li> <li>• Difficulties for low-ability students</li> <li>• Requires familiarisation</li> </ul>	

For understanding the concept of critical thinking, respondent 1 explained that "Critical thinking in chemistry, when students can analyze problems in everyday life related to chemistry". According to respondent 2, critical thinking is when "Children dare to express their opinions according to what they feel and understand based on their life experiences and there is a process of analyzing information", and respondent 3 explained "Critical thinking is when students are accustomed to seeing and solving a problem in more detail". Chemistry teachers in high schools appear to possess a good understanding of critical thinking skills. These results align with research conducted by Seang (2021), which suggests that chemistry teachers possess accurate knowledge of critical thinking. This is likely because some teachers hold bachelor's degrees and lead academic and social lives while studying, which has developed their thinking skills (Seang, 2021). The questions regarding teachers's understanding of chemical literacy and critical thinking indicate that teachers already possess a basic understanding of these concepts. Thus, respondents will realize that teachers have a role not only in teaching material but also as triggers or drivers of positive change. Teachers can encourage students to be chemically literate and think critically through learning, especially assessment (Budiman, Kaniawati, Permanasari, & Lukmana, 2021).

Apart from understanding the concepts of chemical literacy and critical thinking, teachers are also required to train students' chemical literacy and critical thinking skills through their application in learning (Febriyanti & Widjajanti, 2023). Respondent 1 said that the chemistry learning that was carried out had led to the development of chemical literacy. Respondent 2, however, said, "Yes, the teaching materials (books) used ensure that the learning process consistently relates chemistry to everyday life. Not yet in the assessment". Respondent 3 stated, "Yes. The learning methods used are mixed, especially in chemistry. Sometimes there's discussion, sometimes practice. As for assessments, they're only partially questions". In the application of critical thinking in assessments and learning methods, respondent 1 stated that "Some". Respondent 2 said, "Yes, it has. The learning method involves practical work, specifically on chemistry topics, using readily available tools and materials. Students are encouraged to research and design the practical procedures themselves from reference sources, while still being supervised by the teacher. Not all assessments cover critical thinking aspects". Respondent 3 stated, "In the development of assessments and learning processes, it has been directed at the development of critical thinking, but not completely. Trying to link the concept to everyday applications. However, in the calculation section, the critical thinking process has not yet been applied". Based on the interview results, it can be understood that teachers have attempted to integrate chemical literacy and critical thinking into learning. This aligns with Careces et al.'s (2020) statement that critical thinking learning strategies can be implemented through intensive student involvement, independent learning, and discussion. However, this learning remains under the teacher's supervision (Cáceres, Nussbaum, & Ortiz, 2020).

The previous paragraph regarding the application of chemical literacy and critical thinking in learning highlights that, in the chemistry learning process, teachers have sought to connect chemistry learning to everyday contexts (chemical literacy) and to train critical thinking skills. However, assessments that can measure both skills have not yet been developed, which is a problem. Therefore, an assessment is needed that measures both chemical literacy and critical thinking simultaneously and is aligned with the learning process, which already emphasises the application of these skills. The assessments used by teachers in chemistry instruction still focus on memorising concepts, resulting in questions at a low cognitive level. This was stated by respondent 1 that "The cognitive level of questions includes C1 (Remembering), C2 (Understanding), C3 (Applying), ..." and Respondent 2 also stated "The questions developed are mostly at C2. For C3 and C4 (Analyzing) only a few are included in the questions". This differs from Respondent 3, who has utilized a high cognitive level (C4) in his assessment. It can be seen that respondents in making questions have started to use cognitive levels of questions that lead to high-level thinking, although most are still at cognitive levels C1 and C2. According to Jamil et al., (2021), an assessment system that still focuses on memorization will hinder students' critical thinking skills. Therefore, questions must be designed to assess conceptual understanding and reasoning, allowing students to think logically and deeply (Muhammad Jamil et al., 2021).

The teacher further explained his opinion on the advantages and challenges of applying an integrated assessment of chemical literacy and critical thinking. The three respondents answered that the integrated assessment of chemical literacy and critical thinking is excellent if used in learning so that students are accustomed to working on context-based and HOTS questions, this has been explained by Respondent 2, namely "The advantage is that students will be trained to explore and think further, for the disadvantage for students whose abilities and reading are lacking will find it difficult". Respondent 3 also said that "Because students are more focused on results than on the process of digesting and understanding chemical information through assessments, assessments based on chemical literacy and critical thinking have not yet received attention at this school. Even if implemented, they would require prior training". The solution of this challenges is students need to be accustomed to learning and working on assessments that hone their higher-order thinking skills regarding the context of chemistry in life. Science educators also argue that learning in schools should not only teach theory but also encourage students to be aware and brave in facing life's problems (Muhammad Jamil et al., 2021).

However, overcoming these challenges is not easy because other factors mean that integrated assessment instruments to measure chemical literacy and critical thinking have not been implemented. These factors are because the focus of the objectives in schools is not on developing students' chemical literacy and critical thinking skills, the primary focus of teachers in schools when teaching students is being able to complete the material on Time, preparing students to pass exams both at school and higher education entrance exams, and also getting good grades, so that learning becomes meaningless and merely a transfer of knowledge. Students do not understand the essence of their learning chemistry. This needs attention not only from teachers but also from policymakers regarding school curricula. School/educational policies that do not yet pay attention to chemical literacy and critical thinking skills are also a factor in teachers being unable to design or develop integrated assessments of chemical literacy and critical thinking because teachers do not receive special training to create questions based on chemical literacy and critical thinking and there is no encouragement, appreciation, or

monitoring of the implementation of chemical literacy and critical thinking in schools (Cáceres et al., 2020; Muhammad Jamil et al., 2021).

### Needs for Chemical Literacy and Critical Thinking Assessments According to Students

The need for assessing students' chemical literacy and critical thinking was identified through 6 statements that explore information regarding the application of aspects of chemical literacy and critical thinking in question instruments developed by teachers in schools, as well as the need for an integrated assessment of chemical literacy and critical thinking in schools. Item number one of the questionnaire, which concerns students' understanding of chemical concepts, is presented in Figure 1.

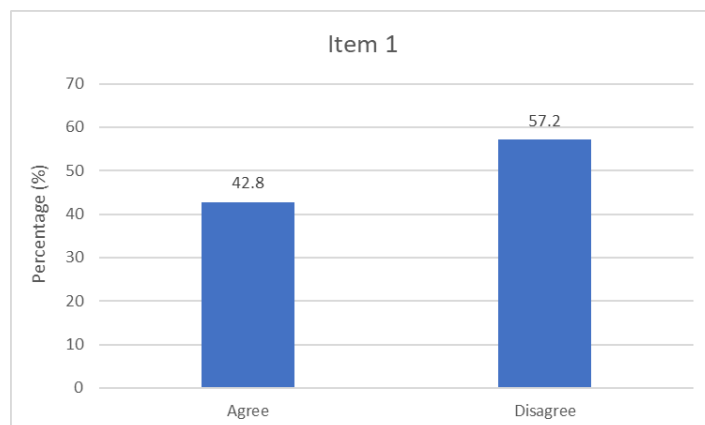


Figure 1. Understanding of Chemical Concepts Students

Caption :

Item 1 : I can relate chemical concepts to their real-world applications.

In Item 1, regarding students' ability to connect chemical concepts to everyday life, 57,2% of students stated they were unable to do so. In comparison, 42,8% of students stated they could understand the chemical concepts they had learned in real-life situations. This may occur because students do not yet understand the chemical concepts themselves; when asked to explain existing phenomena using them, they are unable to do so. Many students consider chemistry material abstract and irrelevant to their lives. Due to these problems, teachers need to make learning (methods and assessments) more meaningful for students by implementing learning based on chemical literacy and critical thinking (Ariefiani & Laksono, 2024; Zidny, Laraswati, & Eilks, 2021). Students' perceptions regarding chemical literacy are reflected in items number 2 to number 4. The students' opinions are presented in Figure 2.

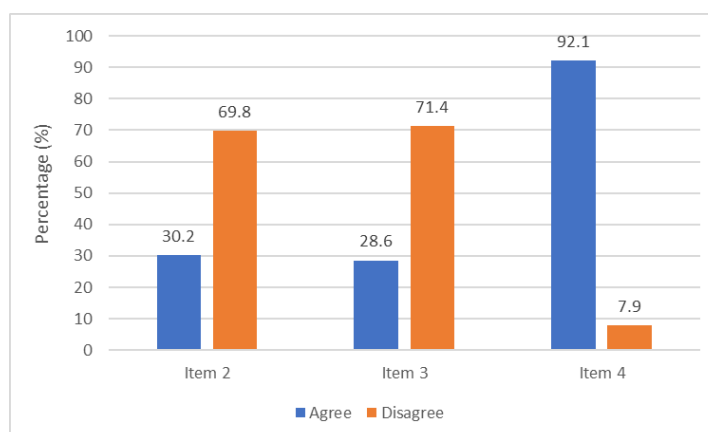


Figure 2. Application of Chemical Literacy

Caption :

Item 2 : The chemistry questions helped me evaluate my understanding of how chemistry applies to daily life

Item 3 : The chemistry questions given relate chemical concepts to events, products, or phenomena that I encounter in my life.

Item 4 : Chemistry questions that are relevant to everyday life make me more interested and motivated to encounter in my life.

In item 2, regarding the application of chemical literacy in questions, 69.8% of students felt that the chemistry questions given by the teacher could not test their understanding of the application of chemistry in everyday life, and 30.2% of students thought that the questions could test their knowledge of the application of chemistry in life. Students also stated in item 3 that 71.4% of the chemistry questions did not connect chemical concepts with events, products, or phenomena in life, and 28.6% felt that the chemistry questions did connect chemical concepts with such events, products, or phenomena. The teacher's chemistry questions lacked context (chemical literacy). In item 4, 92.1% of students stated that if the chemistry questions were relevant to everyday life, they would be more interested and motivated, but 7.9% stated that they were not interested even though the questions were relevant to life problems. Applying the concept of chemical literacy in questions can motivate students to learn chemistry. When learning connects to everyday life, students become more motivated to learn, leading to a more meaningful learning experience. As a result, the knowledge they acquire can be retained in the long term and become useful when applied in real-life situations (Chi, Wang, & Liu, 2023; Retiyanto, Putri, As-Shidiq, & Suyanta, 2023). Students' perceptions regarding critical thinking are reflected in items number 5. The students' opinions are presented in Figure 3.

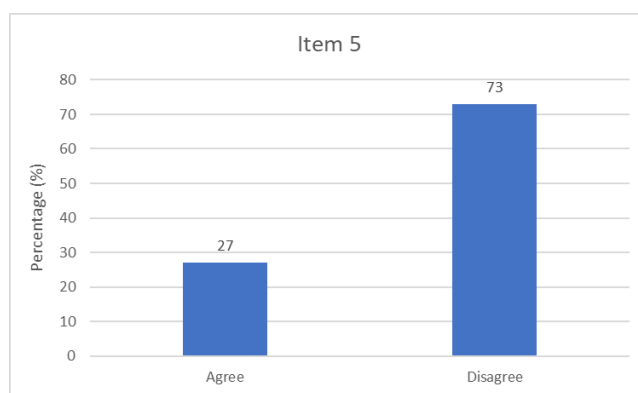


Figure 3. Application of Critical Thinking

Caption :

Item 5 : The chemistry questions provided encouraged me to think critically, including identifying information, building arguments, analyzing data, evaluating information, and drawing conclusions.

According to item 5, 73% of students, the chemistry questions given by the teacher have not encouraged the to think critically. This is evidenced by the large number of students who chose 'Disagree' while only 27% agreed that the chemistry questions given by the teacher have encouraged critical thinking. According to Jamil (2021), if students only memorize material without understanding or thinking, their ability to think critically will be hindered (Muhammad Jamil et al., 2021). The ability to think critically is a skill that can be taught and learned by all the students. Every student has the right to develop and apply these thinking skills, just as they learn other forms of knowledge (Setyorini et al., 2021). Students' perceptions regarding chemical literacy and critical thinking are reflected in item number 6. The students' opinions are presented in Figure 4.

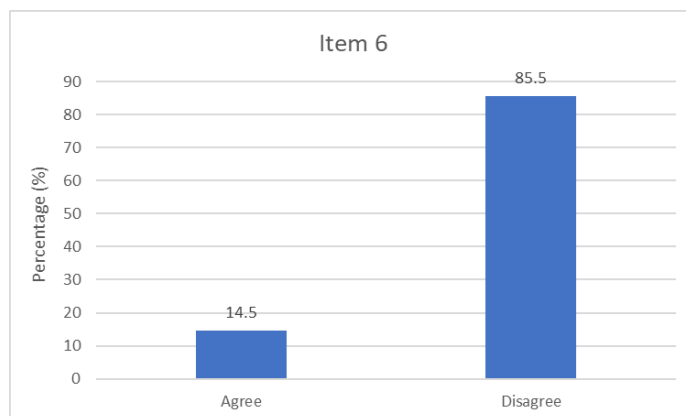


Figure 4. Application of Integrated Chemical Literacy and Critical Thinking

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Caption :

Item 6 : I once encountered a chemistry problem that tested my ability to connect chemical concepts to everyday life and my critical thinking skills simultaneously.

In item 6, the results show that the majority (85.5%) of respondents said they had never encountered questions that tested their ability to connect chemical concepts with everyday life and critical thinking skills simultaneously. Still, 14.5% of students said they had encountered chemistry questions that tested their ability to connect chemical concepts to everyday life while also requiring critical thinking. According to literature, assessments that integrate chemical literacy and critical thinking can strengthen the conceptual understanding through students' active cognitive engagement (S. Sadhu et al., 2019). Based on the analysis of the questionnaire results, students are drawn to aspects of chemistry that are relevant to their lives, making them more interested and motivated to learn chemistry through assessment questions that focus on chemical literacy and critical thinking. Dori said that context-based science and critical thinking can help and improve their understanding of chemical concepts, and students' thinking strategies (Broman, Bernholt, Christensson, Broman, & Bernholt, 2022; Dori et al., 2018; Setyorini et al., 2021).

Assessments need to align with learning objectives. The focus of 21st-century learning is on students' critical thinking skills, enabling them to solve real-life problems. Preparing and creating assessments that align with these learning objectives, specifically integrated assessment instruments for chemical literacy and critical thinking, presents its own challenges. The current school curriculum, the Independent Curriculum, allows schools the freedom to design learning according to student needs. Therefore, schools need to understand the importance of implementing chemical literacy and critical thinking today. Teachers need to develop questions for integrated assessment instruments for chemical literacy and critical thinking. Teachers can learn to develop these assessments through journal articles, which can serve as guidance, or by participating in training, if available. Furthermore, teachers need to consider the relevant context in the questions when developing general chemical literacy and critical thinking questions. Based on research by Broman et al. (2022), students will be more interested in learning chemistry if the approach is contextual and relevant to their personal lives. For example, teachers can raise topics such as food, health, skincare (cosmetics), interests, and hobbies in chemistry questions, but the context remains focused on the chemistry material. Through chemical literacy-based assessments that include problem-solving, students' thinking shifts from lower-order thinking (memorisation) to higher-order thinking (Broman et al., 2022).

A limitation of this study is the small number of participants, which limits generalizability and makes the results less relevant to other contexts. However, this study provides in-depth insights into the need for integrated assessment instruments for chemical literacy and critical thinking, which is helpful for further research aimed at developing such instruments.

## Conclusions

Developing integrated assessment instruments for 21st-century chemical literacy and critical thinking is crucial. A literature review indicates that many previous studies have examined chemical literacy and critical thinking separately. However, measuring both skills (chemical literacy and critical thinking) can yield more comprehensive results. Furthermore, some previous studies have not utilised all aspects of chemical literacy assessment, for example, focusing only on context or competency. Moreover, quality assessment, such as validity, reliability, and index difficulty, requires attention to ensure accurate results for decision-making and improved learning. Empirical studies indicate that teachers already understand the concepts of chemical literacy and critical thinking. This understanding raises teachers' awareness of the urgency of chemical literacy and critical thinking in achieving current science education goals, leading them to design learning activities that train students to think critically about everyday chemistry problems. However, the assessments still primarily measure memorisation of low-cognitive-demand concepts, meaning that chemistry questions do not fully assess students' chemical literacy and critical thinking.

The analysis of student questionnaire responses also showed that many students still had difficulty connecting chemical concepts to real-life situations, with 57,2% reporting they were unable to do so. In comparison, 42,8% of students stated they could understand the chemical concepts they had learned in real-life situations. The chemistry problems given by teachers did not sufficiently test students' understanding of the application of chemistry in everyday life or their critical thinking skills, so they were not optimal for training higher-order thinking skills. 73% of students stated that the assessment questions did not encourage critical thinking, such as identifying information, constructing arguments, analysing data, evaluating information, and drawing conclusions. These findings indicate the need to develop an integrated assessment of chemical literacy and critical thinking, not only to measure students' understanding of chemical concepts, but also to measure and train students' critical thinking skills in solving everyday life problems using chemical concepts, so that teachers

can optimally guide students to become literate and essential learners of science and students gain meaningful learning because the chemistry material is relevant to their lives.

## Acknowledgments

The authors express their gratitude to all research participants and the school authorities for granting permission to conduct the research.

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