Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Analysis of the Chemistry Literacy Profile of High School Students

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Received: May 5, 2026. Accepted: July 10, 2026. Published: October 7, 2026

Abstract: The chemical literacy profile describes the level of students' ability to understand, explain, apply, and analyze chemical concepts within a scientific context. This study employed a descriptive quantitative research design to investigate the chemical literacy skills of Grade 11 Mathematics and Natural Sciences (MIPA) students at MAN 2 Mataram on the topic of petroleum. The sample consisted of 154 students selected from a population of 251 using proportional random sampling. Data were collected through interviews and a chemical literacy test covering petroleum-related concepts. The instrument was evaluated by three expert validators, yielding a content validity coefficient of 0.814, which indicates good validity. Furthermore, all test items met the empirical validity criteria, and the reliability analysis indicated that the instrument was highly reliable. The results indicate that students' chemical literacy can be classified into three aspects. The ability to explain phenomena using chemical concepts achieved a score of 84.25%, which falls into the good category. The ability to apply chemical knowledge to solve problems obtained a score of 85.22%, also categorized as good. The ability to analyze strategies and the benefits of chemical applications achieved 70.78%, corresponding to the fair category. Overall, the average chemical literacy score was 80.10%, indicating a good level of chemical literacy among Grade 11 MIPA students at MAN 2 Mataram. This study provides an empirical overview of students' chemical literacy, serving as a basis for teachers to design more effective instructional strategies, particularly for enhancing analytical skills and the application of chemical concepts.

Keywords: Analysis; Chemistry Literacy Profile; High School Students.

Introduction

One of the challenges in science education in Indonesia is the low level of students' science literacy due to a lack of conceptual understanding of the material taught [1]. Science literacy is an individual's ability to identify a question, acquire knowledge, explain phenomena scientifically, and make decisions based on facts, scientific understanding, and issues related to science [2]. Science literacy is part of the 21st-century skills that students must master to keep pace with global trends. One of the key factors for successfully addressing the challenges of the 21st century is scientific literacy [3]. Individuals who are scientifically literate are expected to utilize their scientific knowledge to solve everyday problems and produce useful scientific innovations.

Scientific literacy can be measured through the PISA study conducted by the OECD (Organisation for Economic Co-operation and Development) every three years. Indonesia has participated in this study since 2000 [4]. PISA study results for Indonesian students' science literacy skills from 2000 to 2022 remain in the low category. Indonesia's PISA science literacy ranking in 2018 was 71st, rising to 67th in 2022. Indonesia's PISA science literacy score in 2018 was 396, then dropped to 383 in 2022 [5]. Science is derived from the term "natural sciences," which encompasses several branches, including physics, chemistry, biology, astronomy, and earth sciences [6].

Chemistry is one of the key science subjects in the high school curriculum. Understanding chemistry has far-reaching implications for everyday life. Chemistry plays a vital role in the development of consumer products, health, energy, the environment, and many other areas. The quality of chemistry learning depends heavily on the extent to which students understand fundamental scientific concepts. Therefore, it is important to assess students' science literacy in chemistry [7].

One topic in chemistry that is closely related to students' daily lives is petroleum. Petroleum is closely linked to chemistry literacy because it is a mixture of chemical compounds frequently used in daily life. Examples of petroleum use include Pertalite and Pertamax in the transportation sector, petrolatum as an ingredient in face creams, and so on.

Based on interviews with chemistry teachers at MAN 2 Mataram, several issues have been identified in the teaching and learning process, including students' difficulty in responding to lessons, teaching methods that remain teacher-centered, and the fact that many students still perceive chemistry as difficult. Students struggle to apply chemical concepts to solve problems they encounter. Students often perceive chemistry material as irrelevant to their needs, not aligned with their abilities and skills, and believe that chemistry cannot be applied in daily life.

Chemistry literacy is the understanding of the properties of matter, chemical reactions, chemical laws and theories, and the general applications of chemistry in everyday life [1]. Students' chemistry literacy involves their ability to understand, apply, and communicate chemical concepts effectively. Students with strong chemistry literacy can relate chemical concepts to everyday phenomena,

How to Cite:
B. A. Zulfa, R. Rahmawati, and B. F. D. Sofia, "Analysis of the Chemistry Literacy Profile of High School Students", *J. Pijar.MIPA*, vol. 21, no. 5, pp. 963–968, Oct. 2026. https://doi.org/10.29303/jpm.v21i5.12018

identify relationships between concepts, and organize their thoughts logically [8]. Measuring chemistry literacy is important to determine students level of chemistry literacy so that they can achieve high or good chemistry literacy, thereby improving the quality of education in Indonesia and enabling it to compete with other countries. Chemistry literacy is essential for investigating and questioning chemical phenomena, fostering critical thinking, developing knowledge, supporting problem-solving and decision-making, promoting environmental awareness, and understanding the values of chemistry [9]. Chemistry literacy equips students to make informed decisions, fosters critical and creative thinking, and helps them solve everyday problems or explain natural phenomena using their knowledge.

According to Shwartz et al., chemical literacy consists of three essential dimensions. The first dimension is explaining phenomena using chemical concepts, which involves interpreting them by applying chemical concepts, terminology, and relevant examples. The second dimension is applying chemical understanding to solve real-world problems. The third dimension is analyzing strategies and the benefits of chemical applications, including understanding the relationship between innovations in chemical processes and their impacts on society, such as the production of pharmaceuticals, fertilizers, and polymers [8]. The factors contributing to low chemistry literacy, based on PISA survey results, are: limited use of student textbooks; student misconceptions or misunderstandings in connecting one concept to another, leading to contradictions with other concepts; non-contextual learning, which prevents students from relating the scientific knowledge they learn to phenomena in everyday life; inadequate school infrastructure and facilities; and human resources, where the quality of teaching staff (teachers) in schools influences all learning activities, which in turn impacts students chemistry literacy [11]. Several issues related to senior high school students' chemistry literacy include difficulties understanding abstract concepts, limited laboratory activities, challenges with chemical language and notation, a dense curriculum, and a lack of active student engagement [12]. Difficulties in understanding chemical concepts can affect students' chemistry literacy, defined as an individual's ability to understand and effectively apply fundamental chemical concepts in everyday life [13].

Efforts undertaken by the government to improve science literacy include the School Literacy Movement (GLS), enhancing teacher competencies through the Teacher Professional Education (PPG) program and the School Driver program, curriculum improvements, textbook revisions, and the use of digital platforms—all aimed at maintaining students' learning motivation and technological skills to address the global challenges of the Fourth Industrial Revolution [11].

Chemistry literacy can be improved by implementing learning that is closely related to everyday activities. Materials using an ethno-chemistry approach can make chemistry learning more engaging and relevant to daily life. The aspects assessed in the chemistry literacy test on petroleum include: the ability to explain the formation of petroleum fractions and the separation techniques used; the ability to identify hydrocarbon combustion and the properties of combustion products; and the ability to propose ideas for addressing and mitigating the impacts of combustion of carbon compounds.

Research Methods

Quantitative research is an approach that extensively relies on numerical data, starting from data collection, data interpretation, and the presentation of results [14]. Quantitative research is also characterized as a type of research activity that is systematic, well-planned, and clearly structured from the initial stage through the development of the research design, including the research objectives, subjects, objects, data samples, data sources, and methodology [15]. The purpose of descriptive research is to provide a systematic, factual, and accurate description or depiction of facts, characteristics, and relationships among the phenomena being studied [16].

This study was conducted at MAN 2 Mataram during the odd semester of the 2024/2025 academic year. This study is a descriptive study using a quantitative approach. The population of this study consisted of all 251 Grade 11 MIPA students from 7 classes at MAN 2 Mataram. The sampling method used proportional random sampling. To determine the sample size for this study, the Slovin formula was used with a significance level of 0.05 (5%). The calculation resulted in a sample of 154 students. A sample is a portion of the population selected as the source of data to represent the population in the study [17].

The research instrument used in this study was a literacy test and interviews to collect data on the chemistry literacy skills of 11th-grade MIPA students at MAN 2 Mataram. The instruments used in this study must first be tested for validity and reliability. This testing was conducted to ensure that the chemistry literacy test instruments to be used are indeed valid for measurement, accurate and reliable, and that the data obtained are accountable.

Expert validation was conducted by two lecturers from the Chemistry Education program at Mataram University and one chemistry teacher at MAN 2 Mataram. Expert validity was calculated using Aiken's V formula. This expert validation involved comparing the instrument's content with the curriculum material that had been taught [17]. Empirical validation, also known as a step to test the instrument developed based on predetermined indicators, involves distributing the questions to students outside the research sample and calculating the results using the biserial correlation (rpbis).

The resulting value is then compared with the value in the table at $r$table. An item is considered valid if $r$pbis is greater than the value in the table at $r$table. The Reliability test was conducted using the Kuder-Richardson (KR-20) formula. The KR-20 formula can only be applied to dichotomous scoring systems. The data analysis technique used to determine students' chemistry literacy skills is quantitative descriptive analysis. The data obtained from the students' answers were then processed and scored. The calculation of the percentage of chemistry literacy skills is as follows.

$$\mathrm{NP} = \frac{\mathrm{R}}{\mathrm{SM}} \mathrm{X}\ 100\%$$

Note:
NP = The percentage score being calculated
R = Total score obtained by the student
SM = Maximum score
100% = Fixed number

The calculation results are interpreted according to the assessment categories. The interpretation of the chemistry literacy test scores is shown in Table 1 below.

Table 1. Chemistry literacy ability categories

Score	Category
86 – 100%	Excellent
76 – 85%	Good
60 – 75%	Poor
55 – 59%	Low
<54%	Very low

Results and Discussion

This is a descriptive study with a quantitative approach, in which the data produced will be numerical. Data were obtained from students' responses to chemistry literacy questions and analyzed using formulas appropriate to the research objectives. The data obtained from this study consist of instrument test results and research results.

Content Validity Test Results

Content validity, also known as expert validity, was assessed by involving three chemistry experts, including two lecturers from the chemistry education program and one high school chemistry teacher. This content validity testing assesses whether the research instrument (question items) is relevant to the aspects being studied [18]. An instrument is considered valid if its Aiken's V value falls within the range of 0.730 to 1.00. The calculation results are shown in Table 2 below.

Table 2. Content validity result

Assessment Aspect	Aiken's V	Description
Material	0.805	Valid
Construction	0.805	Valid
Language	0.833	Highly Valid

Based on the test results above, the research instruments, in terms of content and construct validity, obtained the following values. The instrument received a validity rating of V and, in terms of language, a rating of V with a "very valid" designation. The average V score for the instrument was 0.814, which falls within the valid category.

Empirical Validity Test Results

The empirical validity test was calculated using the biserial correlation formula applied to 35 students outside the research sample. A comparison of the biserial correlation coefficient (pbis) with the table-based correlation coefficient (r) showed that all test items met the $r$valid with a value of the biserial correlation coefficient (pbis)> the table-based correlation coefficient (r). The results of the empirical validity analysis for the biserial correlation coefficient (pbis)fell within the range of 0.344–0.727, where the table-based correlation coefficient (tabel)was 0.333, indicating that all test items of the instrument are valid and the test instrument can be used to measure students' chemistry literacy skills.

Reliability Test Results

A reliability test is conducted to determine whether a measurement tool used in research data collection is reliable. A test is considered reliable if it consistently yields the same results when administered to the same group at different times or on different occasions [20]. The test results were analyzed using the KR-20 formula. A test instrument is considered to have high reliability if the KR-20 test yields a value between 0.61 and 1.00. The results of the data analysis are presented in Table 3 below.

Table 3. Reliability test results

r Value	Description
0.67	High

Based on the r value above, which indicates that the research instrument has high reliability, meaning the instrument exhibits high consistency when measurements are taken at the same time with different subjects, the test instrument can be used.

Chemistry Literacy Ability Data

The validity of the chemistry test for each aspect is shown in Table 4 below.

Table 4. Student literacy skills data

No.	Chemistry Literacy Aspects	Percentage value	Category
1.	Explaining phenomena using chemical concepts	84.25%	Good
2.	Using chemical understanding to solve problems	85.22%	Good
3.	Analyzing strategies and benefits of applying chemical science	70.78%	Poor
Average			80.10%
Category			Good

The chemistry literacy skills of 11th-grade MIPA students at MAN 2 Mataram regarding petroleum-related material fall into the "good" category, with an average score of 80.10%. The percentage of chemistry literacy skills in the aspect of explaining phenomena using chemical concepts was 84.25%, also falling into the "good" category. This indicates that students are proficient in applying their critical thinking skills to solve problems presented in the questions. The indicator for explaining phenomena scientifically is recognizing and explaining problems and events in the

surrounding environment by applying appropriate scientific knowledge [20].

In question 4 on the composition of LPG used daily for cooking, 86.30% of students were aware of the chemical composition of this petroleum fraction and answered correctly, while 13.70% answered incorrectly, indicating that these students were not yet aware of the chemical composition of their surroundings. Question number 5, regarding hazardous gases from the exhaust of fuel-powered motor vehicles, showed that 85.70% of students were already aware of the composition, impacts, and dangers of vehicle exhaust, which they use daily for transportation. Question number 8, which also includes an indicator for explaining phenomena scientifically, tests students' ability to analyze and explain the presented scientific issue, specifically, the greenhouse effect, which is increasingly intensifying. For question number 8, the percentage of correct answers was lower than for other questions due to a lack of understanding of the relevant chemistry.

The greenhouse effect phenomenon, and some students did not understand the graphs presented. The phenomenon of water and oil not mixing is often debated regarding its cause; 84.70% of students explained it using chemical concepts, while the remaining 15.30% were incorrect. Using examples from real-world cases can encourage students to apply their chemical understanding to explain phenomena around them. High scores indicate that students are capable of critical thinking and can analyze scientific phenomena related to the three indicators of the petroleum-based questions, including identifying carbon combustion reactions and their impacts on the environment and health, as well as the properties of petroleum. This first aspect falls within the context domain; students need to be trained to connect subject concepts to their daily lives to develop strong literacy skills [21].

The percentage of students' chemistry literacy in applying chemical understanding to solve problems is 85.22%, which falls into the “good” category. This second aspect is essential because students often face conflicts in their daily lives that require them to make decisions to resolve them. Therefore, chemistry education should not only emphasize conceptual understanding but also ensure that students can apply their understanding and concepts to solve real-life problems related to the material they have studied.

In questions 1 and 12 regarding the uses of petroleum fractions, students demonstrated a high level of proficiency in analyzing petroleum fractions and their applications in daily life, as evidenced by their strong performance on the literacy test. In this aspect, students apply their understanding of chemistry to everyday life, such as understanding the uses of petroleum fractions in transportation, understanding the problems associated with acid rain that poses a danger to life, and so on. Using real-world case studies can help students develop a strong grasp of chemical concepts, enabling them to identify the relationship between chemical concepts and real-world problems.

Students demonstrated high proficiency in solving problems closely related to their daily lives, such as those involving the use of petroleum fractions in common modes of transportation (questions 1 and 12). Regarding the issue of acid rain (question 2), 75.30% of students answered correctly regarding the causes and incomplete reactions of petroleum fractions occurring in this phenomenon; the percentage for question 2 was lower than for other questions because students still lack a clear understanding of the chemical reactions occurring in the surrounding environment, particularly regarding acid rain. Inhaling vehicle exhaust and smoke from fires is a life-threatening issue; 83.10% of students identified the chemical components in the smoke and the dangers they pose to health and life.

One question indicator showed a lower percentage score: the indicator regarding explaining the reactions that occur during the combustion of hydrocarbons. For this indicator, students demonstrated sufficient conceptual understanding, though it was lower than for the other questions. Nevertheless, it would be even better if students possessed conceptual literacy across all the provided question indicators. Students need to be trained to connect concepts from the material to their daily lives to develop strong literacy skills [21]. Thus, chemistry learning is not merely about understanding concepts; students must also be able to apply their understanding and concepts to solve everyday problems related to the topics studied [22].

The percentage of students' chemistry literacy skills in the aspect of analyzing strategies and benefits of chemical applications, at 70.78%, falls into the "adequate" category. The percentage of chemistry literacy skills in this aspect is lower than in the other two aspects. This means that students ability to analyze strategies and benefits of chemical applications can still be further improved. The low level of chemistry literacy in this area may be due to a lack of contextual learning about the application of chemistry in daily life. Contextual learning can train students to connect concepts to everyday life and optimize chemistry literacy in analyzing strategies and applications of chemistry [23]. Understanding the application of chemistry can be enhanced by conducting numerous experiments and reading articles and books on the latest developments and technologies in chemical strategies and applications. This can improve students' chemistry literacy.

The questions in this section focus on strategies and the application of chemistry, addressing strategies or techniques for the safe marketing of petroleum fractions (question 3) and alternatives to the dwindling supply of petroleum (question 11). Many students remain confused about alternatives to petroleum because its use is so deeply embedded in daily life, making it difficult to identify suitable substitutes. Students also continue to struggle to find appropriate solutions to address the problems and phenomena arising from the use of petroleum, as evidenced by their low scores in this area.

There are two question indicators with lower percentage scores: the indicator on determining the impact of petroleum combustion (question number 6) and the indicator on analyzing alternative fuels to replace petroleum (question number 11). These indicators emphasize the need for students to have a broader understanding of the application of increasingly advanced technologies and the diverse uses of chemistry today. There is a need for more active, interactive, and technology-integrated learning (e.g., apps, videos, simulations, and experiments) so that students' knowledge and understanding keep pace with developments

in science and technology. These indicators can be improved through the implementation of contextual [23].

Many factors can influence the level of chemistry literacy among students at MAN 2 Mataram. Based on observations and interviews, an average of 7 to 10 students per class participate in after-school tutoring. This indicates that students' motivation to learn, as well as the roles of parents and the environment, influence their chemistry literacy. This states that student learning outcomes will improve if students have a high interest in learning and adequate facilities [24]. Parental education influences students' chemistry literacy because parents with higher levels of formal education generally differ in their mindsets, aspirations, and perspectives compared to those without formal education [25]. Selecting the appropriate learning models and approaches is also one way to enhance students' chemistry literacy. In addition, teachers must begin using science literacy strategies, such as contextual learning, when introducing and studying material, so that Indonesian students can compete with students from developed countries [26]. Haristy et al. reported that science literacy-based instruction significantly improves students' learning outcomes. This finding suggests a positive relationship between scientific literacy and academic achievement. Therefore, Indonesia's relatively low performance in the Programme for International Student Assessment (PISA), particularly in scientific literacy, indicates that students' science achievement remains below the international average [27].

Individuals with high chemistry literacy can understand basic chemical concepts, explain phenomena, and solve real-life problems using their understanding of chemistry; they can also comprehend chemical innovations in social life and demonstrate a strong interest in chemistry [28]. With good literacy skills, students can develop their critical thinking abilities, which help them observe, collect data, analyze information, and draw conclusions, as well as acquire skills useful in various aspects of life. Students can play a role in addressing global and environmental issues involving chemical concepts, such as climate change and pollution, by better understanding and critically evaluating these problems and contributing to the development of science-based solutions.

Conclusion

Based on the results of the research conducted, the data analysis, and the discussion, it can be concluded that the chemistry literacy skills of 11th-grade students at MAN 2 Mataram in the three aspects of chemistry literacy are as follows: in the aspect of explaining phenomena using chemical concepts, the average score was 84.25%, with students falling into the "good" category; the aspect of using chemical understanding to solve problems had an average score of 85.22%, falling into the "good" category; and the aspect of analyzing strategies and the benefits of applying chemical knowledge had an average score of 70.78%, falling into the "adequate" category. Thus, the overall chemistry literacy ability of 11th-grade MIPA students at MAN 2 Mataram was 80.10%, which falls into the "good" category.

Author's Contribution

B.A. Zulfa: contributed to conceptualization, methodology, investigation, data curation, formal analysis, and writing the original draft; Rahmawati and B.F.D. Sofia participated in the supervision, validation, review, and editing of the manuscript. All authors have read and approved the published version of this manuscript.

Acknowledgements

The author offers all praise and thanks to Allah SWT. By His grace, this research proceeded smoothly and was completed. Thank you to the first and second advisors who guided me throughout the research and the writing of this article. Thank you also to my parents, family, and everyone who has helped throughout the research process, up to and including the publication of this article.

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