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Level of Islamic High Schools Students' Chemistry Literacy

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Abstract

Chemical literacy is a core construct in chemistry education, reflecting students' ability to understand chemical concepts, coordinate macroscopic, sub-microscopic, and symbolic representations, and apply chemistry knowledge meaningfully. In Indonesia, persistent regional disparities in educational quality remain a challenge, particularly in provinces with lower human development indicators. West Nusa Tenggara has recently been identified as a region with relatively high general illiteracy rates, raising concerns about students' chemical literacy at the upper secondary level. This study aimed to investigate the chemical literacy levels of Grade XI students enrolled in State Islamic Senior High Schools across West Nusa Tenggara. A quantitative research design was employed involving 654 students selected through multi-stage cluster sampling based on regional Human Development Index classifications. Data were collected using the Chemical Literacy Instrument (CLI), a validated three-tier diagnostic assessment designed to capture students' conceptual understanding and reasoning across macroscopic, sub-microscopic, and symbolic levels. The instrument consisted of ten items covering core chemistry topics commonly taught in senior secondary education. Descriptive statistical analyses were conducted to categorize students' chemical literacy into nominal, functional, conceptual, and scientific illiteracy levels. The results reveal critically low levels of chemical literacy. Only 12.62% of students demonstrated nominal literacy, 9.16% reached the functional level, and merely 1.12% achieved conceptual literacy, while 77.10% of students were classified as scientifically illiterate. This study provides novel large-scale empirical evidence on chemical literacy in Islamic secondary education contexts within developing regions, highlighting persistent representational and conceptual gaps that remain underexplored in existing chemistry education research. The findings underscore the need for instructional approaches that explicitly support representational competence, diagnostic assessment, and conceptual integration to strengthen chemical literacy development in secondary chemistry education.

Keywords: chemical literacy, literacy, student conception

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1. Introduction

Various developments today have made it easier for us to get everything we need. The era of the Industrial Revolution 4.0 has shifted towards the era of Industry 5.0 where the development of technology and information is so massive and various things we do can be done through automation and digital mechanisms. This then spurs us to be able to adapt to various changes and problems that arise. To face these changes and problems, the OECD (OECD, 2023) published the results of the PISA study which stated that the basic thing needed to be able to adapt and even compete is literacy skills for the community, especially in science literacy competencies.

The public must be made aware of the relationship between science and sociocultural issues so that they can make life choices based on scientific consequences (Herman et al., 2021; Ke et al., 2021; Valladares, 2021). Unfortunately, according to the International Institute for Management Development (IMD, 2022) In its annual report, The Global Competitiveness Report, Indonesia is ranked 44th out of 56 countries, and this is the worst ranking in the last 5 years since 2018 (IMD, 2022). This condition is exacerbated by the achievement of scientific literacy reported by the OECD through the Program for International Student Assessment (PISA) in 2021, which shows that Indonesia is ranked 70th out of 78 countries with a scientific literacy score of 396, far below the global scientific literacy average with a score of 489 (OECD, 2023). This condition at least illustrates that the quality of education, especially science literacy in Indonesia is still relatively low compared to many other countries. Whereas science itself is a discipline that has a direct or indirect relationship to a person's quality of life, both politically, socially, and economically (Holt-Lunstad, 2024; Marginson, 2022).

Furthermore, so far West Nusa Tenggara is ranked second (25,09%) in illiteracy cases in Indonesia for people aged 45+ and ranked third (10,17%) for people aged 15+ (Badan Pusat Statistik Indonesia, 2024). Seeing this position, West Nusa Tenggara must support the movement to increase its public literacy. This movement is not only useful for the process of human development in West Nusa Tenggara but also plays an important role in the process of creating a dynamic, open, and ready-to-face global competition society (Badan Pusat Statistik Provinsi Nusa Tenggara Barat, 2021).

Measurements related to chemical literacy specifically have not been done much when compared to measurements of scientific literacy in general. Generally, developments related to chemical literacy measurements are still associated with five levels of student literacy abilities (Ayuningtyas & Hayati, 2022; Nurlaili et al., 2023). Then, measurements related to chemical literacy are usually limited to certain concepts at a certain grade level. Comprehensive measurements at grade-level segments that cover several materials are still minimal. Measurements made on concepts in grade XI for all materials have not been carried out.

One of the implications of making chemical literacy the goal of chemistry learning is the need to provide precise measurements related to chemical literacy (Haetami et al., 2023; Marfuatun et al., 2024; Wiyarsi et al., 2021). The chemical literacy framework is based on research related to scientific literacy and classified into several categories as scientific illiteracy, nominal scientific literacy, functional scientific literacy, conceptual scientific literacy, and multidimensional scientific literacy (Haetami et al., 2023). A previous study was conducted on Chemistry teacher in West Nusa Tenggara to assess their literacy in the STEAM context (Jannah & Prodjosantoso, 2024) and there is no study that specifically assessing chemical literacy across students in West Nusa Tenggara, especially focusing on State Islamic High Schools. Considering the importance of chemical literacy for the life of the global community in the era of Industry 4.0, researchers are interested in knowing the level of student chemical literacy in West Nusa Tenggara, Indonesia. So, the results of this study can later be part of efforts to improve human competence in the future.

2. Research Method

This type of research is quantitative research to determine the level of chemical literacy in class XI students at State Islamic Senior High Schools in Mataram City, Bima City, and Bima Regency.

The population of this study consisted of grade XI students from State Islamic Senior High Schools in West Nusa Tenggara, considering the distribution of regions with high, medium, and low Human Development Index levels. The samples were selected using multistage or cluster sampling, followed by random sampling, resulting in a total of 654

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grade XI students (Creswell & Creswell, 2023). This approach is time- and cost-efficient while still providing each individual with an equal opportunity to be selected. Therefore, the resulting sample is considered representative of the population, even though the population is widely dispersed.

This study uses a chemical literacy instrument (CLI) in the form of a three-tier test model, which measures students' understanding of chemical concepts at the macroscopic, microscopic, and symbolic levels. In addition to assessing conceptual understanding, this instrument also examines fundamental scientific literacy skills in chemistry, including the ability to explain scientific phenomena using a scientific approach, evaluate and design scientific investigations, and interpret data and scientific evidence.

The instrument used covers grade XI chemistry topics, ranging from petroleum hydrocarbons to acid–base concepts. In general, the test instrument used in this study is presented in Table 1.

Table 1. Chemical Literacy Test Instrument Grid

No.	Topics	Discourse	Question Items	Cognitive Level
1	Petroleum and Hydrocarbons	Types of Natural Gas	1.1; 1.2; 1.3	C3
			2.1; 2.2; 2.3	C4
2	Thermochemistry	Purification of a Substance	3.1; 3.2; 3.3	C3
			4.1; 4.2; 4.3	C4
3	Reaction rate	Sulfur and Cosmetics	5.1; 5.2; 5.3	C3
			6.1; 6.2; 6.3	C4
4	Chemical Equilibrium	Chemical Balance in Our Body	7.1; 7.2; 7.3	C4
			8.1; 8.2; 8.3	C3
5	Acid-Base	Coal and Acid Rain	9.1; 9.2; 9.3	C3
			10.1;10.2;10.3	C4

Each question item is then assessed using a scoring scale of 1–4. For example, in item 3.1, the scoring scale used is presented in Table 2. At the second level, each item is evaluated using the criteria presented in Table 3.

Table 2. Criteria for Assessing First-Level Test Instruments

Score	Criteria
4	If students are able to provide complete and precise explanations, and also examples that are suitable for the concept
3	If students are able to provide an appropriate explanation, but it is incomplete, they should also provide suitable examples related to the concept.
2	If students provide an appropriate explanation, but the examples given are not suitable for the concept
1	If students are unable to provide appropriate concepts and examples

Table 3. Criteria for Assessing the Second-Level Test Instrument

Score	Criteria
4	If students are able to provide > 2 related concepts
3	If students are able to provide 2 related concepts
2	If students are able to provide 1 related concept
1	If students are unable to provide related concepts

The third level of the instrument asks participants to indicate how confident they are in the answers given at the first and second levels. There are five confidence level options that can be selected by the participants, which are: (1) just guessing, (2) very uncertain, (3) uncertain, (4) certain, and (5) very certain. These response options accommodate students who may only be guessing at levels 1

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and 2 (Muryani et al., 2022; Pacala, 2024; Sari et al., 2024; Yeo et al., 2022).

The combination patterns of answers produced by the participants are then used to analyze the students' chemical literacy patterns. The next step is to measure the reliability of the instrument. The results of the reliability analysis using Cronbach's alpha show a value of α = 0.918 for the chemical literacy instrument; therefore, the reliability criterion is met, as the value exceeds the acceptable threshold of α > 0.70.

The respondents' answer patterns on the chemical literacy instrument are categorized based on the classification proposed by Erman, which groups student responses into five categories (Ayuningtyas & Hayati, 2022; Nurlaili et al., 2023). Based on this classification, the hierarchical positions of the respondents' answer patterns can be identified as shown in Table 4.

Table 4. Classification of respondents' answers on the Chemical Literacy instrument

Student score combination			Classification of respondents' answers
Tier 1	Tier 2	Tier 3	
≥ 3	≥ 3	> 3	Conceptual/multidimensional science literacy
≥ 3	≤ 2	> 3	Functional science literacy
≥ 3	≥ 3	≤ 3	Functional science literacy
≤ 2	≥ 3	> 3	Nominal science literacy
≥ 3	≤ 2	≤ 3	Nominal science literacy
≤ 2	≥ 3	≤ 3	Nominal science literacy
≤ 2	≤ 2	> 3	Scientific illiteracy
≤ 2	≤ 2	≤ 3	Scientific illiteracy

3. Result and Discussion

Literacy skills are fundamentally needed as a solution for society to face various changes, especially changes that have a negative impact (OECD, 2023). Considering the importance of literacy skills, especially in chemistry, quantitative data were obtained through three-tier multiple-choice questions related to chemical literacy. The data analysis method in this study was carried out to obtain conclusions. Descriptive and quantitative analysis was used to analyze the data of the instruments tested. This study used the Content Validity Ratio (CVR) model, which is a content validity approach to determine the suitability of items with the domains measured based on expert decisions (Mubarak & Yahdi, 2020). In this study, the CVR value was obtained as 0.99 with a CVI score of 1.83. If we look at the acceptance criteria compiled by, it can be concluded that the instrument used to measure chemical literacy is valid (Masuwai et al., 2024; Sidek et al., 2022).

The reason related to the use of the three-tier instrument test is that it is difficult to measure all aspects and components of chemical literacy using only one instrument with one character (Coldwell & Moore, 2024). So the character of the three-tier instrument test, which has an open-ended type, multiple choice, and Likert scale, becomes better because the instrument variant becomes higher. So, the diverse character of students' chemical literacy can be measured starting from multidimensional literacy to illiteracy.

The overall chemical literacy level of all schools is obtained in the form of a percentage processed based on a combination of student score achievements on each instrument item. These results will provide an overview of whether the student is in one of the five categories of chemical science literacy (Ayuningtyas & Hayati, 2022; Nurlaili et al., 2023), which are, scientific illiteracy, nominal science literacy, functional science literacy, conceptual science literacy, and multidimensional science literacy. The results of the data obtained from all samples are shown in Table 5 below:

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Table 5. Chemical literacy levels of State Islamic Senior High School students in Mataram City, Bima City, and Bima Regency

No.	Categories	Bima City (%)	Bima Regency (%)	Mataram City (%)	Total Percentages (%) n=634
1	Multidimensional Chemical Literacy	0.00	0.00	0.00	0.00
2	conceptual chemical literacy	0.90	0.00	0.22	1.12
3	functional chemical literacy	3.99	1.56	3.61	9.16
4	Nominal chemical literacy	4.09	5.84	2.70	12.62
5	Scientific illiteracy	22.41	25.08	29.61	77.10

In this research, chemical literacy is described in detail for each topic material. There are 5 topic materials used in the instrument. Those topics are petroleum & hydrocarbons, thermochemistry, reaction rates, chemical equilibrium, and acids and bases.

These results highlight a serious gap in chemical literacy among students in West Nusa Tenggara. Despite regional differences, most students struggle to understand or apply chemistry concepts meaningfully.

For regional comparison, Bima City shows slightly better performance in higher literacy levels (0.9% conceptual, 3.99% functional, 4.09% nominal) compared to Bima Regency. On a similar side, Mataram City, while more urbanized, still has the highest percentage of scientific illiteracy (29.61%). Overall, the differences among regions are minor, but all show a consistent trend, low chemical literacy. This indicates that most students have a very limited understanding of chemistry.

Nominal chemical literacy accounts for 12.62% of students, showing some awareness of chemistry but insufficient comprehension. Functional chemical literacy is present in 9.16% of students, meaning only a small portion can use chemical knowledge in daily life. Conceptual and multidimensional literacy, which represent higher-order understanding, are very low (1.12% and 0%, respectively). No student reached the multidimensional level.

The absence of students reaching the multidimensional chemical literacy level is a significant concern (Georgiou & Kyza, 2023). This level represents the ability to integrate chemical knowledge across various contexts, critically analyze information, and apply chemistry concepts to solve real-world problems. The fact that none of the students achieved this level suggests that their understanding of chemistry remains largely limited to memorizing facts rather than reasoning or applying concepts meaningfully (Pardiana, 2024). This condition indicates a lack of higher-order thinking skills such as critical analysis, problem-solving, and decision-making related to scientific issues. As a result, students may struggle to connect chemistry with daily life or broader societal challenges, such as environmental and health issues (Yamtinah et al., 2021). This finding implies that chemistry instruction in these schools may need to adopt more contextual, inquiry-based, and interdisciplinary approaches to foster deeper understanding and promote meaningful scientific literacy.

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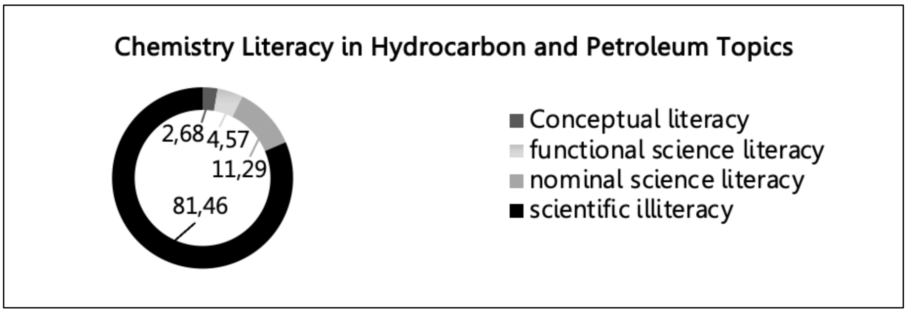

Figure 1. Distribution of Chemistry Literacy Level in Hydrocarbon and Petroleum Topics

In Figure 1, the hydrocarbon and petroleum indicator section, students are introduced to examples of hydrocarbon compounds in the real world, such as liquid petroleum gases (LPG), and then relate these examples to chemical content by depicting the structure of the compound. The contextual approach in this process is oriented towards direct phenomena so that it can find a connection between problems and concepts that have been studied. (Zandroto & Sinaga, 2022).

In the first question, students are asked to describe the differences in the propane and butane gas models if they are in gas form and in liquid form, and determine what is different from the pictures they provide. The pattern of student answers that emerged in answering this question is shown in Figure 2.

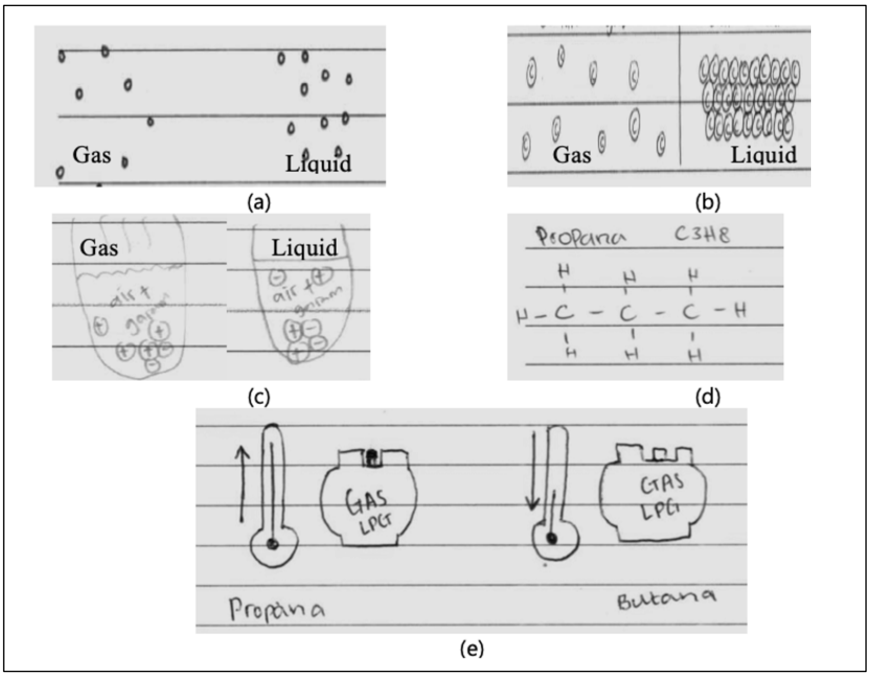

Figure 2. The Pattern of Student Answers Emerged when Answering Questions about Gas and Liquid Phases in Propane or Butane

In answer pattern (a) students well describe the difference in density between a substance in the gas phase and a liquid phase. Answer pattern (b) shows that students are able to show the difference in phase between a gas and a liquid phase; however, the picture of the liquid phase shown is less precise and closer to a representation of the solid phase. Answer pattern (c) shows that students are still confused about what is meant by the phase of a substance and describe propane/butane as an ionic substance. Answer pattern (d) shows

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that students are still unable to understand the request related to the phase of a substance and instead describe the structure of covalent compounds in general rather than describing the gas and liquid phases of propane/butane. The answer pattern (e) shows that students are still unable to understand the concept related to the phase of a substance and the concept of hydrocarbons, and instead describe a container for storing LPG gas.

Based on the answer patterns that appear in Figure 1, the majority of students have not been able to identify and draw the chemical structure of a hydrocarbon compound properly. This is because the understanding of molecular transformation is difficult for students (Abdinejad et al., 2021). Students are asked to be able to change data in descriptive form into visual data (McLure et al., 2022). In order for this to be done properly, students are required to be able to visualize concepts or data and then provide explanations related to the mechanisms they describe (Carle, 2022; Kouril et al., 2023; McLure et al., 2022; Salame & Makki, 2021). Visual representations can only provide insights into scientific data if the viewer is familiar with the concepts of the particular field (Kouril et al., 2023), this is an important skill since students who have high visualization ability are more likely to have better memory retention and enhanced understanding of the concepts (Gargrish et al., 2021). In this case, students have difficulty in determining the phase of substances microscopically and show their weaknesses in this microscopic chemical representation (Popova & Jones, 2021).

Other difficulties are also encountered in describing possible chemical bonds resulting from changes in pressure on certain hydrocarbon compounds. This shows that students' weakness in applying and finding the integration of compound properties that are influenced by different molecular structures, because students' knowledge is limited to relying on memorization (Zandroto & Sinaga, 2022).

Chemical bonding is an important concept and will be used in various properties of compounds and their changes during certain chemical reactions or mechanisms (Hunter et al., 2022). However, many difficulties faced by students make this seem like something difficult to understand. Therefore, visualizing and providing explanations for the images given will greatly help students improve their understanding. In addition, in learning, students are given the opportunity and space to be able to dialogue about the visual imagination that they describe with what they should describe (Kouril et al., 2023; Salame & Makki, 2021).

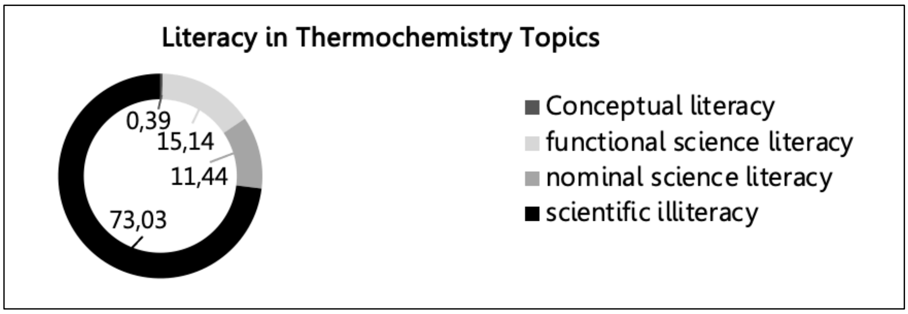

Figure 3. Distribution of Chemistry Literacy Level in Thermochemistry Topics

In Figure 3 shows that most students are at the scientific illiteracy level and do not reach the multidimensional literacy level (Yuliana et al., 2021). Additionally, students struggle to understand the concepts of endothermic and exothermic reactions. This is because students do not understand how the interaction between the environment and the system (Sutarja & Wulandari, 2021). There are still many students who have not been able to write theoretical bases by explaining the concepts and theories regarding the

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experiments carried out, so this makes students unable to state the reasons for exothermic and endothermic reactions in their answers (Rosyidah et al., 2024).

There has been a lot of research conducted to reveal students' difficulties in understanding thermochemical concepts, this also includes understanding the concepts of exothermic and endothermic reactions well (Rosyidah et al., 2024). Other reports on difficulties in understanding concepts related to exothermic and endothermic revealed that students had more difficulty in understanding basic concepts related to theory compared to calculations. This is an indication that students prioritize memorization rather than well-understanding on thermochemistry material (Sihaloho et al., 2021).

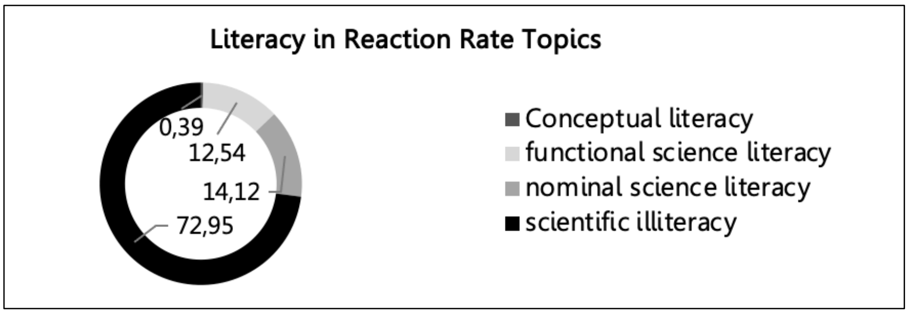

Figure 4. Distribution of Chemistry Literacy Level in Reaction Rate Topics

Figure 4 indicates that most students cannot define chemical concepts that are considered familiar to them. Their definitions of concepts are mostly wrong and are at the macroscopic level. In this topic, what is done is to read data and graphs and determine the most economically profitable graph pattern based on the data displayed. Many students were able to calculate various descriptive statistics, but some of them were still unable to determine suitable statistics to describe the data clearly (Setiawan & Sukoco, 2021).

However, this is a very important thing. Stating something based on data and claiming that the data and statements produced are true is an important part of the inquiry stage, and creating scientific arguments (Muntholib et al., 2020). Students are asked to be able to change data in descriptive form into visual data, such a graphics or diagrams. Students do rise to the challenge of representing their scientific causal explanations, including dynamic relationships and abstract concepts, when drawing a series of diagrams (McLure et al., 2022). In order for this to be done well, students are required to be able to visualize data and provide explanations related to the mechanisms they describe (Kouril et al., 2023; Salame & Makki, 2021). Students are also asked to logically assess which reaction is the most effective and efficient so that it can be economically profitable. This will require students to make a logical sequence of the given reaction rate data.

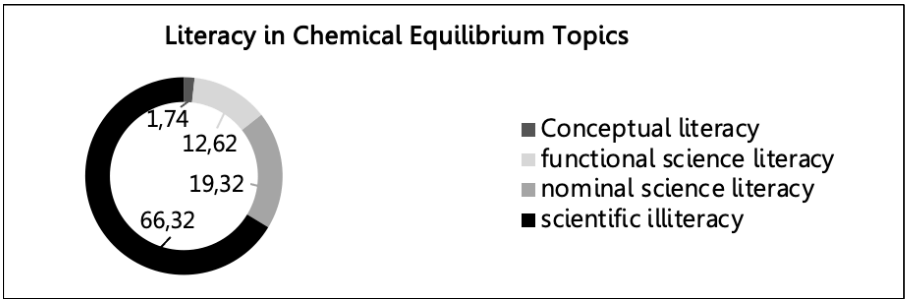

Figure 5. Distribution of Chemistry Literacy Level in Chemical Equilibrium Topics

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Figure 5 shows that the majority of students are still in the scientific illiteracy category. In another study, chemical literacy steps based on chemical equilibrium material using an integrated assessment instrument showed that students' abilities were in the low category, with an average in the medium category (Syamsidar & Suyanta, 2024). Chemical equilibrium itself is a topic that is considered quite difficult in chemistry learning (Ekiz-Kiran et al., 2021; Khairani & Prodjosantoso, 2023; Siregar & Mawardi, 2022), this is because this topic involves several previous concepts such as the properties of matter, and chemical bonds, as well as more difficult concepts such as concentration and reaction rates (Khairani & Prodjosantoso, 2023).

In this topic, students are asked to write down the equilibrium reaction equation formed based on the given discourse. Students have difficulty recognizing the names and types of compounds involved in the reaction. The number stated in the illiteracy category is also high because they do not understand how the mechanism of a reaction occurs. Students have difficulty determining which compounds act as reactants and products from a given discourse. Students often struggle to build strong arguments and use scientific principles appropriately to justify their claims. There may even be students who fill in the answers without knowing why a reaction can occur (Lieber & Graulich, 2022). The chemical concept approach in our body is important to understand well. This helps us understand the mechanism of how our body works and how our body reacts chemically. The unfortunate thing is that most students have difficulty explaining this microscopically due to a lack of understanding related to microscopic chemistry, microscopic thinking habits, and also stuttering in communicating scientifically (Carle, 2022; Lieber & Graulich, 2022).

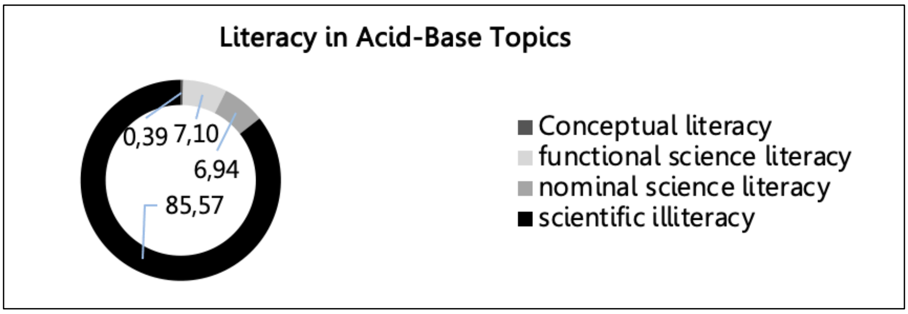

Figure 6. Distribution of Chemistry Literacy Level in Acid-base Topics

Figure 6 shows similar data with other topics' level of literacy, that the majority of students are in the scientific illiteracy category. This is in accordance with the findings of other studies, in a survey conducted on 64 respondents showed the average chemical literacy score of survey participants was 57.75% (moderate category) (Primadianningsih et al., 2023; Riska & Guspatni, 2022). On this topic of acids and bases, participants were given a discourse related to acid rain, which is a socio-scientific issue that often occurs (Ban & Mahmud, 2023; Wiyarsi et al., 2021). This is intended to measure students' understanding of how acid rain can form micro-molecularly and what acid-base mechanisms play a role. Students are asked to analyze the compounds involved in the formation of acids and bases and which one act as acids and bases in the given reaction and analyze the impacts that occur in the environment when acid rain continues to occur. Both of these will require students to think both microscopically and macroscopically.

The results of the sample test showed a small group that understood the concept of acid rain well. However, this proportion is very far from the 85.57% of the sample, who were unable to understand and master topics related to acid rain and indicated scientific illiteracy in understanding the concept of

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acids, bases, and acid rain. This weakness could also be caused by the teacher not following developments related to socio-scientific issues (Badeo & Duque, 2022) and having weaknesses in understanding phenomena related to acid rain. This is as reported by where there are around 41% of teachers who are unable to understand and provide explanations or have limited knowledge and experience related to socio-scientific issues, which indicates that teachers are not used to thinking critically and including empirical scientific reasons related to their understanding (Chen & Xiao, 2021; Hernández-Ramos et al., 2021).

In addition, understanding the Lewis acid-base mechanism is important in understanding chemistry as a whole, apart from the Arrhenius or Bronsted-Lowry acid-base concepts. Advanced topics in chemistry, such as organic or inorganic chemistry, require students' understanding of the role of the Lewis acid-base concept (Boothe et al., 2023; Derman et al., 2024; Fanguy & Kharbash, 2023). However, it appears that students are unable to accurately identify which compounds in the discourse are lewis acids and bases in the given reaction. This is mean that students were unable to properly identify lewis acid-base compounds, even though they were able to identify Bronsted-Lowry acid-base compounds well (Boothe et al., 2023).

4. Conclusion

In this study, the author describes the level of chemical literacy in MAN students in Mataram City, Bima City, and Bima Regency. The author obtained the data by providing a chemical literacy test instrument to grade XI students in MAN in Mataram City, Bima City, and Bima Regency. From the results of the study, it was obtained that the level of chemical literacy of MAN students in Mataram City, Bima City, and Bima Regency, based on the respondents used, was at a very low level of either at nominal chemical literacy, functional chemical literacy, or conceptual chemical literacy, and considered at a high level of scientific illiteracy.

This study has limitations, particularly because the context is limited to a specific institution or student characteristics. The measurement tools used may not be fully comprehensive for social presence, cognitive presence, teaching presence, and technological presence. Additionally, there is a lack of consideration of external factors such as student motivation or socioeconomic conditions that may affect student literacy or learning outcomes.

Expanding the research to larger, more diverse populations and evaluating its sustained effectiveness in various disciplines would provide deeper insights.

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