

Analysis of Students' Chemical Literacy Skills with Scientific Information: Case Study During Covid-19

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Abstract. Chemistry education students as a future chemistry teacher should have a good science literacy/chemical literacy in order to deliver chemistry knowledge to be applied in the future. Therefore, this study describes the chemical literacy skills of students of the Chemistry Education Study Program. The aim of this study is to investigate the chemical literacy levels related to chemistry concepts through a case study of global information during the covid-19 pandemic. A range of chemical literacy aspects is measured, which include nominal (recognizing chemistry concepts); functional (defining key concepts); conceptual (utilizing chemistry knowledge to describe daily phenomena); multi-dimensional literacy (utilizing chemistry knowledge to analyze information in a short article or other reading sources). The research method of this study is quantitative descriptive. Participants of the study were 112 students of the Chemistry Education Program who had already taken basic chemistry courses. The instrument used to obtain data on students' chemical literacy levels was questionnaires using the Likert scales (three options) and open-ended questions. The findings show that the percentage of students' nominal, functional, conceptual, and multi-dimensional literacy skills are 78.21, 60.54, 51.48, and 44.08% respectively. The findings indicated that students' chemical literacy skills are in the average range and need to be improved.

Keywords: chemical literacy skills, pandemic, scientific information, global information

Introduction

The world has been shocked by the pandemic outbreak that emerged at the end of 2019. On December 31st, 2019, new cases of pneumonia of unknown aetiology were reported in Wuhan, Hubei Province, China. On January 9, 2020, the Centre for Disease Control and Prevention (CDC) of China reported a new coronavirus strain as the pandemic-causing agent; it later became known as coronavirus 2019 (covid-19) disease (ECDC, 2020). On April 25th, 2020, the Government of the Republic of Indonesia reported 8,607 covid-19-confirmed patients in the country. The figure included 720 deaths related to covid-19, while 1,402 had recovered from the disease. The World Health Organization (WHO), along with the Indonesian Government, have continued monitoring the covid-19 situation in Indonesia and are actively preventing the spread of the disease (WHO, 2020).

The covid-19 pandemic has upset society, which has been motivated to find actions to avoid the plague. There are several actions that can be taken to avoid outbreaks of infection, for example: usual hand washing, covering each nose and mouth during sneezing

and coughing, altogether cooking meat and eggs. Maintain a strategic distance from near contact with anybody appearing indications of respiratory sickness like sneezing and coughing (Mohammed et al., 2020). Information about the virus, and ways to prevent and cure the disease it causes, are distributed on a massive scale in online media such as websites, social media, and chat (conversation) platforms. One of the important current issues in responding to the covid-19 outbreak is how to handle the spreading of information – the "info-demic" – since not only valid information but also misleading information (hoaxes) related to the pandemic is being disseminated all over the world. Therefore, scientific knowledge about such information is extremely needed; it plays an important role in information literacy.

The global effort to fight covid-19 relies heavily on establishing how to persuade people to change their behaviour, to ensure they gain holistic knowledge about what to do and not do in their response (IFLA, 2020). Good scientific literacy helps both the individual and the community to be more critical and smarter in receiving information, and in acting correctly based on that information.

Chemistry is one of the important branches of science. Generally, it teaches us about materials, and understanding the characteristics of important materials used in many applied areas of knowledge, such as medicine, geography, physics, the environment, and economics. Learning chemistry enables students to understand everything that happens in their surroundings (Sirhan, 2007). Besides, recent years have shown that the utilization of chemistry knowledge directly or indirectly plays an important role in our daily lives as consumers. It can also affect people's decision-making in many fields; in medicine, for example, information about nutrition and meal choices that affect metabolism and boost immunity may influence one's eating habits.

A complex and fast-changing world needs some basic understanding of chemistry (Gilbert & Treagust, 2009) because such knowledge contributes to scientific literacy, which is widely considered as the main object of science. Scientific literacy embodies scientific ideas, concepts, and practices in many disciplines (Shwartz et al., 2006b). Scientific literacy is an important issue today because it can influence a person's decisions. According to Henriksen & Froyland (2000) and Fitria (2017), the importance of scientific literacy is useful for understanding and dealing with problems in everyday life in society. It has become a critical issue to discuss in recent decades, making students realize that the benefit of literacy is the main concern of teachers, scientists, and curriculum makers (Martinez-Hernandez et al., 2015).

Information about covid-19 has become sought-after, not only in sciences like medicine and chemistry, but also in other disciplines. It can be accessed through various media including TV programs, newspapers (both online and offline), and the internet. Through these sources, students and other people can become an educated community regarding this issue, which is relevant to chemical literacy (Show-Yu, 2009).

Questionnaire results from 29 students majoring in the Chemistry Education Program about the reception and management of online information during the pandemic show that information is gained mostly from online media – both social media and chat platforms. Most of the information received is scientific information consisting of chemistry concepts, including references. The way students manage this information is divided into two types. Some of them read and find valid sources before spreading the information, and others blindly apply and spread the information received without reading it carefully and checking its validity. This pattern leads to the possibility of massive dissemination of misleading information, which affects individuals' and society's decision-making. This also closely relates to students' literacy in understanding information they receive, selecting relevant and beneficial information from broadcasts, connecting information to valid and relevant material, and applying/utilizing information where they can decide or solve a new problem in a complex situation.

These factors show the importance of scientific literacy to the community at all levels, including students, since scientific literacy is needed to build a strong national social foundation. Thus, science/chemistry literacy skills is needed to promote the 21st century skills (Cigdemoglu et al., 2017; Liu, 2009; Rahayu, 2017). To understand the role of scientific/chemical literacy, the case-study research about students who have learned chemistry is needed in order to find out their chemistry literacy level during the covid-19 pandemic, because they will play a role in delivering chemistry knowledge to be applied in the future. In addition to that, this study analyzed the actual state of literacy which is specific to students' chemical literacy skill and its relationship with the chemistry concepts understanding. The purpose of the study is to analyze student's chemical literacy with scientific information during the covid-19.

Methods

This is descriptive research with a quantitative and qualitative approach. Quantitative approach used to respond to research questions requiring numerical data, the qualitative approach for research questions requiring textural data, and the mixed methods approach for research questions requiring both numerical and textural data (Carrie, 2007). This study portrays a situation/occurrence in a factual, systematic, and accurate way using quantitative – qualitative data and then describes the findings to analyse and create deeper insight into chemical literacy ability among Chemistry Education Program students in the Faculty of Teacher Training and Education, Universitas Tanjungpura. The whole population of this research comprises active students from the Chemistry Education Program in the academic year 2020/2021 that have taken basic chemistry courses. Samples were chosen using a cluster random sampling method to obtain 112 students.

Data collection techniques were based on indirect communication techniques, calculation techniques, and direct communication techniques. The methods used were literacy questionnaires using a Likert scale instrument, and chemical literacy tests in the form of open-ended questions. The instruments were then validated by two experts using experts' judgement score suggested by Gregory (2015). Where a comparison of the number of items from two experts as validators with strong relevance to the entire items category. The result of the relevancy tabulation (contingency tables) is presented in Table 1, the validity coefficient is presented in Formula 1.

Table 1. Interrater agreement model for content validity.

		Expert Judge #1	
Expert Judge #2	Weak Relevance (Item rated 1 or 2)	Weak Relevance (Item rated 1 or 2)	Strong Relevance (Item rated 3 or 4)
	Strong Relevance (Item rated 3 or 4)	A C	B D

$$\text{Content Validity} = \left(\frac{D}{A+B+C+D} \right) \quad (1)$$

Description:

- A: The number of items in cell A (weak-weak relevance)
- B: The number of items in cell B (strong-weak relevance)
- C: The number of items in cell C (weak-strong relevance)
- D: The number of items in cell D (strong-strong relevance)

Then, the result of validation compared with the category proposed by Gregory (2015). Table 2 shows the category of validation by Gregory.

Table 2. Category of validation.

Range Score	Category
0.80 – 1.00	Very Good
0.60 – 0.79	Good
0.40 – 0.59	Enough
0.20 – 0.39	Poor
0.00 – 0.19	Very Poor

The data analysis technique employed to gauge the students' literacy ability was based on questionnaire results and responses to open-ended questions, supported by interview results. Questionnaire data was employed to measure the nominal ability level analyzed using the Likert scale. The questionnaire digs into the extent of students' understanding and familiarity with given terms and concepts. The Likert scale in the questionnaire offered three alternative points. It was framed in the form of statements followed by respondents' choices: T (*Tahu* – know), CT (*Cukup Tahu* – somewhat know), and TT (*Tidak Tahu* – do not know). The score for each choice on this Likert scale is T = 3, CT = 2, TT = 1 (Shwartz et al., 2006b).

Open-ended questions data was used to determine functional, conceptual, and multi-dimensional ability levels. Problems presented at a functional level tested the students' understanding of definitions of concepts or terms. Explanations of definitions were based on two concepts, at the macroscopic and molecular levels. The determination of conceptual and multi-dimensional ability levels was achieved by offering a discourse from hoax news circulating online through news and social media. The students were then given questions regarding the discourse. Their answers were categorized into true, partly true, and false. Totals and percentages of the data were calculated to see the distribution of students' chemical literacy levels within a) nominal literacy (recognizing chemical concept); b) functional literacy (defining key concepts); c) conceptual literacy (utilizing chemistry knowledge to describe daily phenomena); d) multi-dimensional literacy (utilizing chemistry knowledge to analyze information in a short article or other reading sources).

Results and Discussion

Students' ability at every chemical literacy level was interpreted by assuming that the concepts should have been learned by them in class, and there were references about scientific method. Thus, the description can portray their chemistry literacy ability generally, and was expected to be able to measure their literacy levels on any chemical concepts, as well as their ability to connect what was taught in class with manifestations of chemical literacy. Students' abilities at each chemical literacy level were presented in Figure 1.

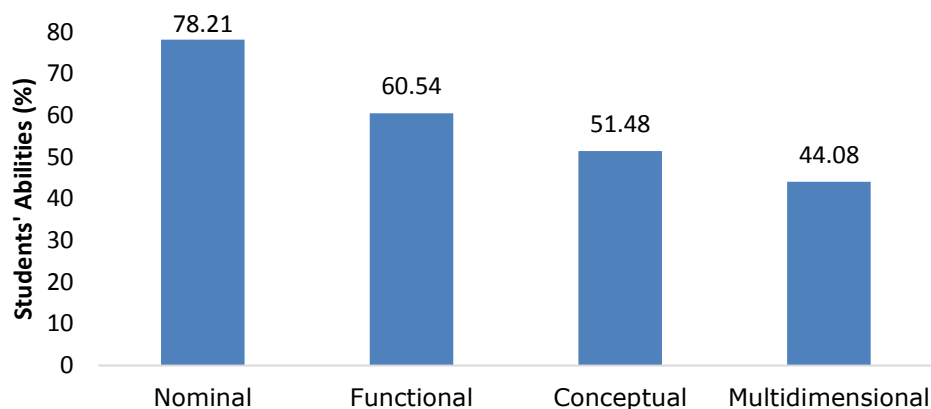


Figure 1. Graph of students' abilities at each literacy level

Nominal Literacy

Students' nominal literacy ability was measured using a questionnaire intended to measure the extent of students' familiarity or understanding of chemistry concepts or terms. The questionnaire given to measure nominal literacy includes general chemistry concept and scientific investigation, sub-microscopic, general and specific types of chemical substances, and chemistry concepts related to chemical reactions. Table 3 below shows the grouping of these concepts. While, the average students' nominal literacy ability about various chemistry concepts (Scale 1-3) can be seen in Figure 2.

Table 3. The grouping of chemistry concepts.

No	Category	Concept
1.	General chemistry concept	Stoichiometry, chemical nomenclature, pH, concentration, conclusion, facts, the scientific method
2.	Sub-microscopic concept	Atoms, ions, molecules, chemical bonds, electrons, isotopes
3.	Material: common chemical substances	Acids, bases, solutions, solvents, elements, compounds, polymers, fatty acids
4.	Material: specific chemical substances	Vinegar, alcohol, hydrogen peroxide, glycerol, sodium hypochlorite, phenolphthalein, hand sanitizer, aquabidest
5.	Concepts related to chemical reactions	Chemical reactions, reaction rates, equilibrium reactions, electrolysis

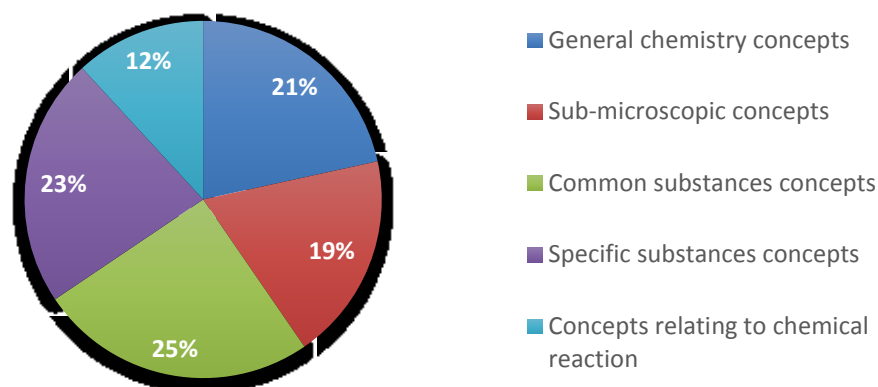


Figure 2. The average students' nominal literacy ability about various chemistry concepts (scale 1-3)

Questionnaire results about students' knowledge of chemistry concepts, or their familiarity with several chemistry terms or concepts, showed that the students understood various aspects of chemistry concepts. These results can be seen in Figure 1. The relatively high score for most categories, above 2.5, presented in Figure 2 shows that most students are familiar with many chemistry concepts. This especially applies to concepts including the common chemical substances category, specific chemical substances category, general chemistry concepts, and scientific investigation. However, concepts related to the sub-microscopic category and chemical reactions are less familiar to the students, with an average score below 2.5 (maximum score is 3).

Students have difficulty understanding sub-microscopic concepts (Gilbert & Treagust, 2009). While according to Treagust et al. (2003) effective learning at a relational level of understanding requires simultaneous use of sub-microscopic and symbolic representations in chemical explanations. These problems can be caused by their misunderstanding of sub-microscopic concepts – for example, their misunderstanding of the particulate characteristic of a material (Harrison & Treagust, 2006), or their inability to visualise a chemical entity when it is represented in a sub-microscopic manner (Tuckey & Selvaratnam, 1993).

Another unfamiliar concept, or knowledge that students lack, relates to chemical reactions. A study showed Chandrasegaran et al. (2014) that understanding of chemical reaction concepts, such as chemical equilibrium, reversible chemical reaction, catalyst effect, or inert gas in an equilibrium system, is very limited. Several chemical reactions need to be learned by chemistry students, i.e., types of synthesis chemical reactions, decomposition, combustion, and others. However, studies revealed that chemistry students cannot differentiate or understand all of these reactions (Surif et al., 2018). According to Özmen & Ayas (2003), senior high school students face problems at various levels to understand and master five basic concepts of chemistry. For example, students tend to assume changes happening in a substance, such as freezing or evaporation, constitutes a chemical reaction while in fact, it is a change only in its physical condition, not a chemical change.

Many students also find difficulty in writing a reaction equation of chemical equilibrium. This might happen because many students are incapable of imagining changes that happen in an atom when the chemical reaction occurs (Eilks et al., 2007; Surif et al., 2018). Some chemical terms or concepts given were unfamiliar to the students. Figure 3 shows that students are not accustomed to, or are unfamiliar with, aquabidest (distilled water), sodium hypochlorite, phenolphthalein, glycerol, and polymer terms or concepts.

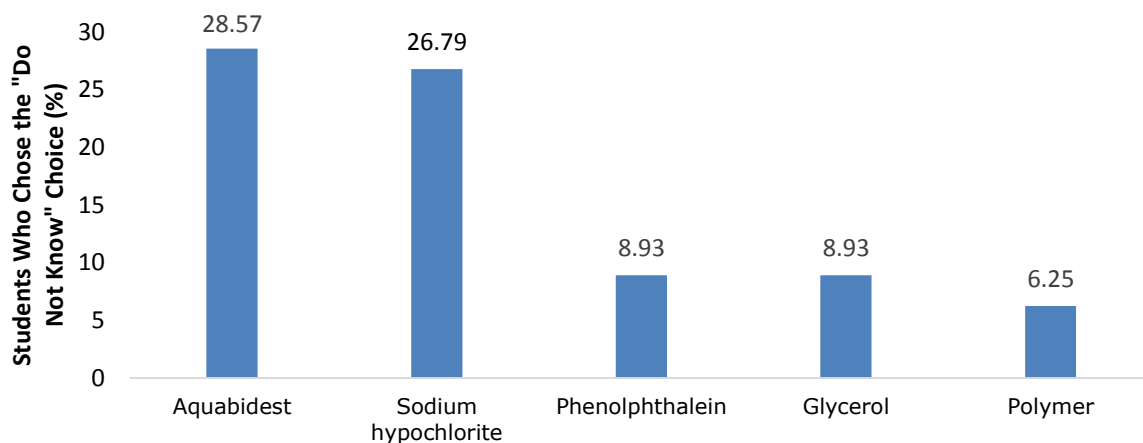


Figure 3. The percentage of students who chose the "do not know" choice (these are the top five most unfamiliar concepts)

Those five concepts are included in the chemical substance categories; the first four terms are specific substances, while the last one, polymer, is a common chemical substance. A few students were unfamiliar with other names or other references for a type of substance. The term aquabidest is the most unfamiliar concept to students. Aquabidest (aquabidestilata) is water produced from the distillation process in stages (a two-times distillation process) and contains minerals that are far less than aquadest. Students are more familiar with aquadest / distilled water terms because this solvent is often used in the laboratory during laboratory practice.

Students are also unfamiliar with sodium hypochlorite as one of the chemical materials employed to make disinfectant. Sodium hypochlorite is another term for natrium hypochlorite. In chemical packaging, the ingredient is usually written using the 'sodium' term instead of 'natrium'. This shows that students are more familiar with chemical substance nomenclature as written in the periodic table of elements compared to that written on chemical material labels. It suggests an introduction is required to various terms for substances, such as sodium as another name for natrium, or phenolphthalein's abbreviation to 'pp indicator'. Names for chemical materials given in lectures – both basic chemistry and advanced – will surely contribute to nominal chemistry literacy levels: the introduction of the chemical concept.

Functional Literacy

Functional literacy is the ability to use scientific concepts to read and write about science and technology (Fahmina et al., 2019). Functional literacy levels were measured using open-ended questions. Open-ended questions were given to the students to find out their ability in identifying and defining the chemistry concepts. The students' explanations or answers about numerous chemical concepts were categorised into (1) false or meaningless answers, (2) partly true, which means the answer has some true parts but is not accurate or complete, and (3) true. The students' answers were also categorised into whether their explanation contained a molecular or macroscopic element, including some elements of chemistry terms denoted by a symbol or molecular image. Therefore, the assessment consists of six categories: answers that contain a molecular element and are true, partly true, or false, and answers that contain a macroscopic element, and are true, partly true, or false. The percentage of students' answers on various concepts were presented in Table 4.

Table 4. The percentage of students' answers on various concepts.

Concept	Type of Answer	True (%)	Partly True (%)	False (%)
Ion	Macroscopic	10.26	83.33	6.41
	Molecular	83.33	10.26	6.41
Acid	Macroscopic	57.69	33.33	8.97
	Molecular	3.85	53.85	42.31
Alcohol	Macroscopic	32.05	62.82	5.13
	Molecular	10.26	74.36	15.38
Concentration	Macroscopic	62.82	25.64	11.54
	Molecular	6.41	12.82	80.77
pH	Macroscopic	10.26	85.90	3.85
	Molecular	3.85	17.95	78.21
Equilibrium Reaction	Macroscopic	17.95	58.97	23.08
	Molecular	3.85	8.97	87.18

Table 4 presents the percentage of students who chose true, partly true, and false answers. The results conveyed in Table 2 suggest a few interesting trends, i.e.:

- (1) More than 50% of students can respond correctly about acid and concentration concepts, but even their correct answers explain the concept only on a macroscopic level. Only regarding the ion concept can the students give a correct answer while explaining the concept at the macroscopic and molecular level.
- (2) Most students answer partly true on all items, which means that only some components are correct, while not accurate or incomplete, except those concerning acid and concentration.
- (3) In general, students tend to explain more about concepts at the macroscopic level than those at the molecular level, except regarding the ion concept.
- (4) More than 78% of students cannot explain the pH concept, concentration, or equilibrium reaction at the molecular level.

Students are richer in chemical terminology when describing acid and concentration concepts. The definition of an acid is explained by including the definition of acid by experts or scientists, and the interpretation of concentration also contains examples of different units and concentration measurements. such as molarity, molality, percent by volume, percent by weight, etc. Students' answers imply that they have more knowledge about certain items, as demonstrated when they use more chemical vocabulary. However, their answers also indicate that most of them cannot use the knowledge correctly. For example, most students explain the concentration concept without referring to its molecular level, merely writing down the symbols and formulas of various concentration calculations.

The explanations of the ion concept were limited to an atom that has charge, ions consist of cations and anions, the anion is a positively charged ion and the anion is a negatively charged ion. The explanation at the molecular level provided only the example of an ion that has one atom, such as Na^+ and Cl^- , whereas an ion occurs not only in atomic form but can also be a group of atoms that carries an electric charge by losing or adding electrons, such as NO_3^- , PO_4^{3-} which are called polyatomic ions.

Conceptual Literacy

In this study, students' conceptual literacy skills are based on the ability to express a correct understanding of chemical concepts in explaining everyday phenomena. The results showed that most students still lacked the ability to use the knowledge gained in learning chemistry through lectures in different contexts, such as an explanation of the application of chemistry in daily activities. The results on conceptual literacy are presented in Table 5.

Based on Table 5, students are asked questions about making a solution with a certain concentration from a main ingredient that also has a certain concentration. In making 70% alcohol-based disinfectants, a small proportion of students were able to describe the method of diluting 96% alcohol and to provide calculations in determining how much volume enables the dilution to produce 70% alcohol. On the other hand, some students were able to explain only the dilution principle in making a solution. Similar results were returned in regard to the manufacture of disinfectant solutions based on sodium hypochlorite. The number of students able to explain the preparation of the solution with the concentration range recommended by LIPI was very small. Most of the students did not observe the labels on the main ingredients; the initial concentration used in the preparation of the disinfectant is indicated on the label.

Table 5. Percentage of students' performance on conceptual literacy.

Conceptual	Correct (%)	Half Correct (%)	Wrong (%)
Making alcohol 70% from alcohol 96%	26.32	47.36	26.32
Preparation of disinfectant from 10% sodium hypochlorite into concentrations in the range 0.05-0.5%	5.26	55.26	39.48

Multi-dimensional literacy

Multi-dimensional literacy is demonstrated through the ability to read and to analyse articles sourced from information provided. For affirmative dimension of chemical literacy people should have a realistic view about chemistry (Shwartz et al., 2005, 2006a). Students with multi-dimensional scientific literacy develop an understanding and appreciation of science and technology, and their relationship to everyday life (Yuenyong & Narjaikaew, 2009). More specifically, students begin to make connections within a discipline and between disciplines, as well as between science, technology, and the larger problems facing our society (Bybee & McCrae, 2011).

Assessing all aspects of multi-dimensional literacy within chemistry literacy will be very complex, and not all of them fall within the scope of the objectives of this research. In this study, the discourse or information provided is from an event closely related to everyday life, especially during the covid-19 pandemic. The discourse given comes from websites / sites that contain fake scientific information that has grown massively on social media and online news sites. The assessment of these elements is limited to very specific aspects, namely the ability to read and understand discourse based on information circulating on online media and social media, and the relationship between chemistry and personal or social aspects. The ability to read, understand, relate new information to previous knowledge, and to criticise are important components of the skill dimension within the definition of chemical literacy.

The results show that students still have low ability to read and criticise an article. Take, for example, the discourse on the disinfectant booth. A similar result also reported by (Fahmina et al., 2019). Most of the students considered that the disinfectant booth was

beneficial in preventing the spread of the virus where humans, as virus carriers, would be sprayed with liquids such as those containing alcohol or sodium hypochlorite. Based on discourse, it has been shown that sodium hypochlorite packaging labels indicate that this substance has corrosive and toxic properties. Therefore, its use in a disinfectant chamber, where it will be sprayed on humans, is not recommended. Likewise, in the manufacture of hand sanitizers exemplified in information disseminated through social media, the manufacturing formula does not follow WHO standards. If the concentration of alcohol produced from the hand sanitizer is less than 70%, then the hand sanitizer will not be effective in killing the virus. There were students who wrote down how to make a disinfectant using a bottle cap, even though the cap fails to give a clear measurement, so cannot be used as a reference in making a solution to a specific formula. This low ability shows that students understand what they are reading (reading comprehension) but cannot relate it to previous chemistry knowledge and show a low level of reasoning ability. Another reason proposed by Hayati (2017), students' inability of multi-dimensional aspect due to students were not adjusted to use the assessment that revealed a high-level thinking skill. To improve students' literacy (Wiyarsi et al., 2020) and (Utami et al., 2022) suggested to use real-life experiences as discussion platform in context-based learning. Moreover, Habibati et al. (2019) and Panjaitan et al. (2021) informed that the use of handout and booklet could enhance students' science literacy and understanding.

Conclusion

The highest level of student chemistry literacy is nominal, where students exhibit very rich chemistry vocabularies when answering the questions. Meanwhile, students with functional and conceptual literacy are still at the medium level. Multi-dimensional literacy of the students was in the lowest level. It is expected that the findings of this research can be used as the basis which will help further research by using the various learning strategy, including teaching and learning resources, that may help increasing students' chemical literacy skills. The alternative solution to improve chemical literacy skill by using innovative chemistry instruction such as inquiry, constructivist approach, socioscientific/contemporary issues, nature of science, and collaborative, communication and curiosity. In the learning process, teachers can also use a 'multiple representations' approach to improve their skills in explaining at the molecular level.

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