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Evaluation of Senior High School Students' Ability to Reading Chemistry Text

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ABSTRACT

Science text reading activities can introduce students to understanding chemical concepts and practice reading skills. Reading skills play an important role in science education because they are related to student's cognitive and metacognitive abilities. This study aims to see the students' ability to read texts and their understanding of chemical concepts through texts. This research uses a mixed method design and embedded type. Quantitative data is obtained through survey results, and qualitative data is obtained through interviews to strengthen the justification for the quantitative data obtained. Participants in this study were 299 high school students in the cities of Malang and Batu. The research instrument is an instrument for reading chemistry text skills (r = 0.918) consisting of 3 chemistry texts, and in each of them, there are 8 essay questions covering literal, interpretation, and application aspects. The profile of students' reading skills based on the results of surveys and interviews shows that most students' reading skills have not been able to understand the idea of chemical concepts correctly, have not been able to describe chemical terms in the text correctly, students' explanations of chemical concepts are at the structural level, and have not been able to provide creative ideas (arguments) for solutions to problems presented in the text. The implications of this study need to be explicit skills in reading chemistry texts to understand chemical concepts and be proficient in reading chemistry texts.

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1. INTRODUCTION

Improving scientific literacy is a goal in science education (Webb, 2010). Educators should promote the goal by engaging students in practicing science (Holbrook & Rannikmae, 2007; Krajcik & Sutherland, 2010). A form of practicing science is the ability to read and understand scientific texts (Fang & Wei, 2010; Norris & Phillips, 2003; Yarden, 2009). Thus, emphasizing scientific reading is essential in science education to help students develop reading literacy that eventually makes them scientifically literate citizens (Stoddart, 2016; Wellington & Osborne, 2001; Yore, 2012). Moreover, reading scientific text has been used to promote conceptual understanding (Sinatra & Broughton, 2011), and scientific process skills

(Bethlehem, 2009) and is part of the basic literacy in science (Norris & Phillips, 2003) that students are supposed to master.

However, the results of the 2018 PISA study showed that the reading literacy of 77% of students aged 15 – 16 years on average across OECD countries is at level 2. Indonesian students' reading literacy also reaches level 2. According to PISA, benchmarks for successful student success in reading literacy include students' skills in obtaining information, interpreting text, and evaluating and reflecting on a text (OECD, 2018). Level 2 is basic skills (low level) which includes the student's ability to identify the main idea of the text in a text of moderate length expressed explicitly (OECD, 2019b). Meanwhile, only 8.7% of students from the average across OECD countries reached the top level, level 5, or level 6. At these levels, students can comprehend a lengthy text, deal with abstract concepts, and establish the distinction between fact and opinion. In the results of the 2023 PISA for Indonesian students, the average reading decreased by -12 points including low-performing students (OECD, 2019b). The PISA result indicates that students' reading skills need to be improved.

Students can learn about science, the scientific method, or scientific concepts through reading science texts, doing laboratory activities, or from their everyday lives (Lemke, 1990). Reading science texts is defined as students' ability to absorb, interpret, and analyze information written in science texts and relate it to their prior knowledge to build meaning or scientific knowledge (Fang & Wei, 2010; Geranmayeh, 2016; McNamara & Magliano, 2009). Several studies related to the skills of reading science texts in science learning (e.g., chemistry, physics, mathematics, biology) focused on: 1) differences in the skills of expert and novice readers in building conclusions (Van Lacum et al., 2012); 2) correlation of language comprehension skills with learning outcomes (Pyburn et al., 2013, 2014); 3) the influence of genre or type of text on students' understanding of concepts (Al-Balushi & Al-Harthy, 2015; Araújo et al., 2015; Désiron et al., 2018; Dori et al., 2018; Karasinski, 2016), and 4) understanding of meaning dual terms in science learning (Song & Carheden, 2014). However, research investigating skills in reading specific texts, such as science texts (e.g., chemistry) is still rare (Wang et al., 2014), including reading skills in specific texts at the level of high school students is still not widely carried out, especially in Indonesia. Given the importance of reading science texts skills in developing scientific literacy, this research needs to be done to evaluate the skills of reading chemistry texts for high school students. This study aimed to evaluate the skills of reading chemistry texts and provides a reference for measuring high school students' chemistry text reading skills using the essay method in literal, interpretation, and application aspects**.**

Science texts are essential for understanding scientific information, characterized by their distinct nature compared to other texts. These texts serve as a form of scientific communication within society, playing crucial roles in three main areas: facilitating communication among scientists, bridging scientists and the public, and serving educational purposes to prepare students for active participation in the scientific community (Goldman & Bisanz, 2002). Different genres of science texts, including scientific journals and popular media, cater to these varied audiences. Scientific texts exhibit unique features such as specific syntax rules, specialized vocabulary, and the use of multiple representations like diagrams and chemical formulas. These elements require readers to have foundational knowledge in science to avoid misconceptions and to accurately interpret scientific concepts (Walsh, 1982; Jacob, 2001; Schmidt et al., 1989). Understanding these texts involves recognizing the dual meanings of scientific terms and the specialized syntax and semantics used in scientific communication (Song & Carheden, 2014; Désiron et al., 2018).

Reading skill is a complex process that involves cognitive and metacognitive processes in a person to build an understanding or mental model (OECD, 2019b; Yore, 2012). The OECD (OECD, 2019b) defines reading as the ability to understand, use, and reflect on written texts as a form of integrating issues/texts with existing knowledge to develop knowledge and skills and apply their knowledge in social life. To determine the level of reading skills, it is necessary to evaluate these skills.

Especially reading skills on specific topics such as chemistry. The language of chemistry can be a source of problems in learning the concept of substance. For example, in research conducted by Song & Carheden (2014), students still have difficulty understanding chemical terms so that they have difficulty in understanding chemical concepts comprehensively. Thus, it is necessary to offer teachers new didactic tools to develop chemistry language teaching. One of them develops assessments related to chemical language such as the assessment of reading skills in chemistry.

One of the studies related to reading skills in chemistry is research exploring the basic notions of the language of chemistry (Canac & Kermen, 2016). The research shows that there are still many students who do not understand about writing chemical formulas outside the context of chemical equations and are unable to associate macroscopic and microscopic criteria. Another study that assessed the understanding of chemical language using (CLA) (Ress, Kind, & Newton, 2018). CLA assesses the comprehension of scientific affixes, symbolic language, non-technical words, technical words, base words, and topic-specific vocabulary. Results showed that comprehension of chemical language improved during the study period with moderate to large effect sizes. Students who scored low on the initial CLA (below 40%) improved but their grades remained lower than other students at the end of the year. These studies have the effect of identifying chemistry teaching challenges, one of which is due to a lack of understanding of language.

The aspects measured in reading skill assessments can vary based on the assessment's purpose. This research focuses on the literal aspect of reading skills. Dori et al. (2018) examined high school students' understanding of chemistry concepts through comprehensive reading of science texts, assessing their ability to identify main ideas and chemical concepts, and explain these concepts textually and visually. However, evaluating reading skills in specific subjects like chemistry is rare. This study's instruments are based on constructs of reading skills (literal aspects, interpretation, and application) (Basaraba et al., 2013), cognitive processes in understanding text (OECD, 2018), and understanding chemistry through text (Dori et al., 2018). Literal aspect evaluation aims to gauge students' grasp of chemical concepts and terminology. Interpretation aspect evaluation assesses their ability to identify and interpret chemical representations and explanations of concepts or phenomena. Application aspect evaluation measures students' creative and evaluative thinking in constructing arguments. Thus, this study aims to evaluate high school students' reading skills in chemistry texts, hypothesizing that reading proficiency may differ based on the types of scientific information presented.

2. METHODS

This study employed a mixed-methods design, an embedded type (Creswell, 2009), and utilized quantitative data-gathering approaches in the form of surveys. To ensure the credibility of the survey results, it was required to re-confirm certain findings using structured interviews to acquire appropriate qualitative data. The researcher gathers numerical data, scrutinizes the findings, and then gathers qualitative data via structured interviews.

2.1 Participants

Participants in this study consisted of 358 grade XI students randomly drawn from 4 high schools in East Java, Indonesia, and they voluntarily participated in the research. Representative sample selection follows the five-step model illustrated in Figure 1. The first step in the sample selection process is determining the target group (population), namely all high school students in Malang and Batu City. The selection of SMAN as a population is based on the Indonesian government's policy on the high school student admission system, which uses a zoning system so that each school represents the condition of students in each area of Malang and Batu cities. In the cities of Malang and Batu, there are 12 zoning SMAN (10 in the city of Malang and 2 in the city of Batu). The second step is to select grade XI students close to completing upper secondary-level education. Class XI is considered to have gained enough knowledge of chemistry and reading skills even though the chemistry material obtained by students has not been throughout class XII. The third step is to select class XI students who have taken the material to the topic of acid-base. In the fourth step, there are 4 high schools in the cities of Malang and Batu (2 schools in the city of Malang and 2 schools in the city of Batu) which were selected as a research sample with a total of 420 students and mapped the area of the student's residence (residence). In the fifth step, from 420 students who shared the Google Form link, 358 students who voluntarily filled out a survey on Google Form, and 299 answers that could be analyzed as research data.

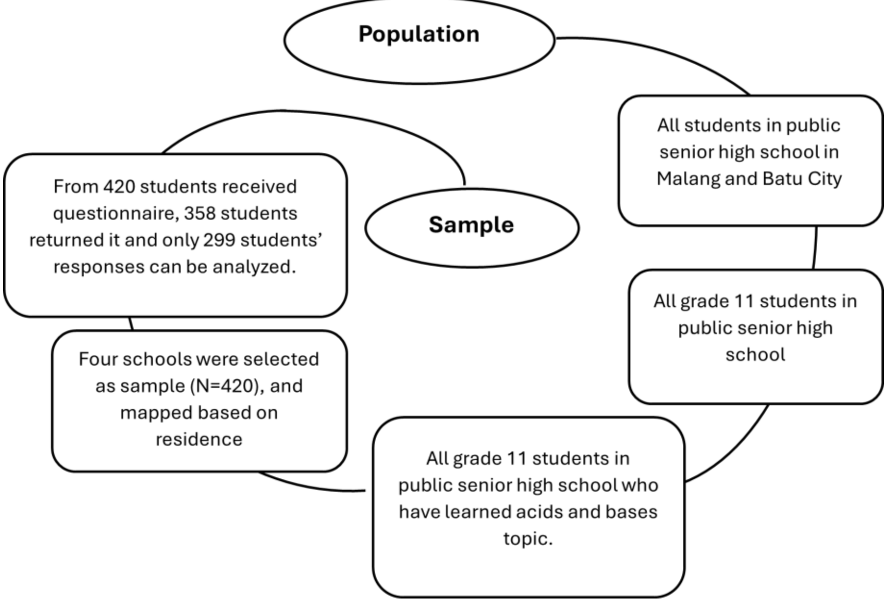


Figure 1. Scoring literation aspect – identification of the main concept

The instrument was distributed via Google Form link to all participants (N=420) because there was a COVID-19 pandemic then, so the research was carried out online per government policy. Of all these students, only 299 student responses (58.5% female and 41.5% male) could be analyzed as data to be used as research samples. From 299 samples, 34.8% of students came from rural areas and 65.2% from urban areas. The characteristics of the sample description in this study are given in Table 1.

Table 1. Sample description (N=299)

Varian	Frequency	%
Sex		
Female	175	58,5%
Male	124	41,5%
School type		
Students in Public School	299	100%
Residence		
Students in rural public school	104	34,8%
Students in urban public school	195	65,2%

2.2 Instrument development

This data collection procedure consists of two stages, namely 1) the instrument development and trial stage, and 2) the data collection stage.

Phase 1: Instrument Development and Trials.

The research instrument was developed by adopting the instrument development steps carried out by (Chandrasegaran et al., 2007), which consisted of four steps, namely:

Step 1 – determine the content of the chemical material. The determination of chemical content is carried out by analyzing the applicable chemistry curriculum with the following criteria: 1) chemical content allows it to be studied through a text related to chemical concepts and can be related to controversial chemical issues, and 2) chemistry content has been taught to the class to be the subject of research. One of the chemical contents that meets both criteria is a buffer solution. The buffer solution content in the curriculum has competencies that students must master, namely, students can analyze the role of buffer solutions in the bodies of living things and be competent in designing, conducting, and concluding, as well as presenting experimental results to determine the properties of buffer solutions. Buffer solutions have a very important role in chemical and biological systems and are closely related to controversial issues. For example, the issue of acidification of the ocean contains the concept of buffering solution and the issue is controversial and widely used as a context for studying chemistry (Dori et al., 2018; Moon et al., 2019).

Step 2 – determine the reading skill indicators to be measured. The process of determining indicators of reading skills is carried out by a literature review. Based on the literature review, it is known that in reading science texts students need to translate symbols and integrate their initial knowledge and beliefs (McNamara et al., 2007; Perfetti et al., 2005; Souvignier & Mokhlesgerami, 2006) and represent text (Van den Broek, 2010) to interpret the text. Three things can be measured in students' reading skills, namely how students interpret texts explicitly (literally) and implied (integrating) which can build the meaning of student knowledge and lead students to be able to think creatively. This is in line with three aspects of reading skills, namely literal, interpretive, and application aspects (Basaraba et al., 2013; Burns et al., 1999). However, this study wanted to measure the reading skills of science texts related to chemical materials and intended for students studying chemistry. Therefore, this aspect of reading skills is adjusted to the chemical characteristics adopted from the instrument that has been developed (Dori et al., 2018). In this study, the indicators of chemical text reading skills measured were: 1) Literal aspects, evaluating students' understanding of chemical concepts that became the main ideas and chemical terms; 2) The interpretation aspect evaluates students' ability to identify and interpret chemical representations presented in texts as well as explanations of chemical concepts or phenomena; and 3) The application aspect evaluates students' ability to think creatively and evaluatively in the context of compiling written arguments.

Step 3 – develop instrument reading skills. The stages of instrument development used in this study are: (1) determining competency indicators based on aspects of skills as a basis for developing texts and questions and reading skills assessment rubrics; (2) discussing instruments and measurement indicators with experts and validating instruments. Reading competency indicators are developed based on aspects of reading skills. First, questions developed based on literal aspects are concerned with students' skills in identifying ideas of major chemical concepts in the text, and these chemistry terms amount to two essay questions. Second, questions developed based on interpretation aspects are related to students' skills in identifying and interpreting chemical representations presented in texts and explanations of chemical concepts or phenomena, as well as questions two essay questions. Third, questions developed based on application aspects related to students' ability to think creatively in the context of compiling written arguments, the number of questions one essay question.

To provide an assessment of students' answers, an assessment rubric was developed based on scoring criteria. The scoring criteria for indicators of ability to identify the main ideas and key chemical concepts that become ideas in the text are a score of 0 if the student answers incorrectly/does not answer; a score of 1 if the student is not precise in identifying the idea of chemical concepts; score 2 if students can correctly identify the idea of a chemical concept; A score of 3 identifies idea A and provides a brief description of the chemical concept. The scoring criteria for the identification indicators of chemical terms are score 0 if the student answers incorrectly/does not answer; score 1 if the student identifies fewer than five chemistry terms; score 2 if students identify fewer than five chemical terms and describe/define them appropriately; A score of 3, if the student identifies more than five chemical terms and describes/, defines them appropriately.

Table 2. Reliability Instrument

	Reliability Instrument	
	Cronbach's alpha	Descriptions
All items (N=27)	0,924	Reliable
Item of literal aspect (N=9)	0,854	Reliable
Item of interpretation aspect (N=12)	0,882	Reliable
Item of application aspect (N=3)	0,775	Reliable

The scoring criteria for identifying and interpreting chemical representations in a text are as follows: score 0 for incorrect or no answers; score 1 for interpreting one chemical representation; score 2 for two representations; and score 3 for three representations. For explaining chemical concepts or phenomena scientifically, the Solo taxonomy (Biggs & Collis, 1982) is used: score 0 for irrelevant or non-answers (prestructural); score 1 for surface-level understanding of one aspect (unistructural); score 2 for understanding multiple independent aspects (multistructural); score 3 for relating multiple aspects (relational); and score 4 for a comprehensive understanding that applies concepts in various contexts.

The scoring criteria for indicators for writing argument preparation are guided by the elements of Toulmin's argument (Toulmin, 2003). The criteria for scoring arguments are a score of 0 if the student's argument is irrelevant, a score of 1 if the argument compiled by the student consists of elements of claims only; a score of 2 if the argument prepared by the student consists of elements of claim and justification (warrant) and/or data; Score 3 if the argument compiled by students consists of elements of claims supported by data, warrants, or backings and contradictions (rebuttals).

Step 4 - Validate the instrument to an expert. The draft instrument was given to two chemistry education experts. The aspects validated by the two experts include content feasibility, presentation feasibility, language, and graphics. Based on the results of the validation of the feasibility aspect, the content was targeted based on reading skills and chemical content. The question items reflect reading skills (literal, interpretive, and applicative). The feasibility aspect of the presentation gets suggestions to improve the layout of the image placement. Experts provide advice related to linguistic aspects, namely the need to add a prompt to help students understand questions related to the term "chemical representation". This is because the term "chemical representation" is unfamiliar to high school students so it can be considered confusing. Furthermore, validation was carried out on 24 questions where in each text there 8 questions were representing literal, interpretation, and application aspects. All question items were validated with the help of SPSS software, and 15 valid questions were obtained.

Step 5 – Piloting the instrument reading skills. Before the questionnaire instrument is used, reliability and validity tests are carried out on students in classes that are not used for participant samples. The results of the validity test using SPSS obtained that 27 questioner question items were declared valid and reliable (r = 0.924) so that the instrument could be used (Tavakol & Dennick, 2011). Reliability results are seen from Cronbach's alpha value with SPSS presented in Table 2. As in Table 2, reliable instruments can be used to conduct surveys.

Phase 2: Data collection

Data for analysis is collected both quantitatively and qualitatively in sequence. Quantitative data is gathered via online surveys using Google Forms. Qualitative data is collected through semi-structured interviews with eight students, with two students representing each reading skill level. After obtaining permission from the Malang City Education Office, high schools, and participating students, the Google Forms link is distributed to students through chemistry teacher coordinators at four high schools in Malang City. Students have one day to complete the survey, as all are attending school online from home and have varying access to the necessary technology.

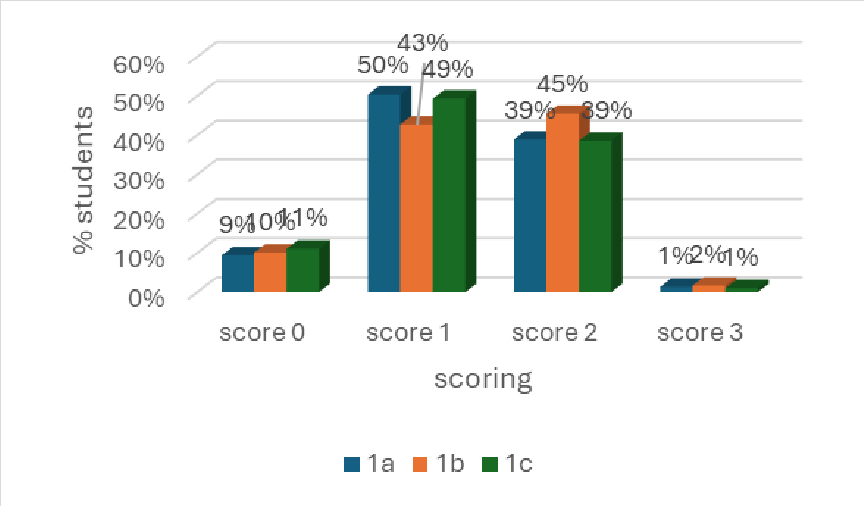


Figure 2. Scoring literation aspect – identification of the main concept

After the data is collected, all students' answers are scored, and grouped based on scoring references. To determine the level of student scoring accuracy, an interrater reliability analysis of student answer assessment was carried out by two raters. The data used for interrater reliability analysis was 30% participant data (N = 90). Based on the results of interrater reliability tests with SPSS software, it is known that the value of the kappa coefficient (K) = 0.844 and p-value = 0.000 (kappa coefficient (K) > 0.6 and p-value < 0.05) so that it can be concluded that there is almost no difference in perception (almost perfect) between raters in assessing the answers of participants in the survey.

3. FINDINGS AND DISCUSSION

After going through limited tests, it is known that the instrument can be used to conduct surveys. The results of high school students' chemistry text reading skills were obtained from descriptive statistical data and analyzed for every aspect of reading skills.

3.1 Literal aspect

The literal aspect is a basic reading skill related to the ability to code, identify, and decipher words/terms and main ideas in a text (William, 1988). Research findings show that the highest average achievement of students is at a score of 1 (N above 43%) and 2 (above 39%). This shows that most students cannot yet correctly identify the ideas of key chemical concepts.

Only a small percentage of students can identify ideas of chemical concepts and describe them appropriately (score 3, N = 1-2%). Here are some examples of students' answers in each scoring group to the question about the main idea: "Write and describe the main idea / main idea of the text (Should we care about CO_2 emissions?) by using your language".

Students with a score of 1 tend to rewrite one of the sentences in the first paragraph (not in their own language) rewrite the title of the text or infer the main idea based on the last paragraph in the text (Table 3). This suggests that students do not infer the main idea of the chemical concept presented but rather tend to determine the main idea in a quick way that they remember without paying attention to the overall content of the text. As confirmed in the interview, here is the quote

> "*Because usually the main idea lies at the beginning or end of the sentence. So, I think what is conveyed at the beginning of the text is the main idea.*".

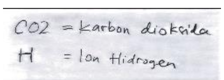
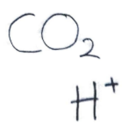
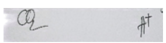
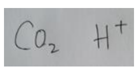
The results of this interview showed low motivation to read students. This is reinforced by the results of research by Nida, et. al., (2020) based on the results of interviews with teachers showed that students have low motivation and reading comprehension. The answer pattern of students on score 2 has a different answer pattern from students on score 1 (Table 3). In students with a score of 2, they can identify one of the main ideas/main ideas correctly. The pattern in students score 3 is more than one main idea in the text (Table 3). However, what distinguishes students score 4 from others is that students score 4 in completeness of conveying the main idea of the text (Table 3). Students scoring 2 to 4 have been able to identify chemical terms correctly, but the difference is that students on scores 3 & 4 include a description of the definition for each term mentioned and the number of chemical terms that can be written (Table 3).

Table 3. Summary of sample of students' answers on the literal aspect

	Skor 1	Skor 2	Skor 3	Skor 3
Identify the main idea	Tiana: Our oceans absorb 22 million tons of CO_2 this can cause a decrease in the pH of the ocean caused by carbonate dynamics in the ocean.	Nata: The main idea is ocean acidification.	Name: In my opinion, the main idea of the text is ocean acidification as it relates to ocean buffer systems.	Samara: The main idea of the text is the issue of the phenomenon of sea acidification due to the disruption of the ocean buffer system. The buffer system is the ability of a solution to maintain pH. The phenomenon of ocean acidification results in a decrease in the pH of the ocean due to fuel combustion and CO_2 emissions. A decrease in the pH of the ocean will adversely affect animals in the ocean, especially those whose body skeletons are made of calcite, $CaCO_3$, Calcite reacts with acids that interfere with its growth.

The limitation of this study is using Google Forms, so it is necessary to confirm the writing of some chemical symbols (such as writing CO_2, and H_2CO_3) to students through interviews because GOOGLE Form has limitations for writing that requires subscript and/or superscripts). Based on the interview results, it is known that students on score 1 do not fully understand the meaning of writing chemical symbols shown by expressions and doubts in answering interview questions. Students on scores 2 and 3 tended to use memory recall while students on score 4, were able to explain well enough to demonstrate their understanding of chemical concepts. Excerpts of the interview are presented in Table 4.

Table 4. Summary of sample of students' interview

Interviewer Questions	Skor 1	Skor 2	Skor 3	Skor 3
Express the chemical formula of carbon dioxide gas and hydrogen ion	Tiana: 	Nata: 	Name: 	Samara: 
Why do you write that?	Tiana: (for hydrogen ions) Yes, it's like that, right, ma'am.. eeh.. what's wrong, huh.. I don't know	Nata: Because if you write a compound like that but for ions write it above.	Name: Because CO_2 gas has a C atom, it is only written C and 2 O atoms, so the way to write is the number of O atoms below. If	Samara: Because if you write an empirical formula, you write the symbol of the atom followed by the number of atoms

Interviewer Questions	Skor 1	Skor 2	Skor 3	Skor 3
			hydrogen is group 1, then the charge is +1, he wrote above.	written below. So, carbon dioxide is written CO_2 (pointing to the result of the writing. If the ion is written the atomic symbol followed by the number of charges above, then the hydrogen ion is written like that (pointing to the writing H^+) because group 1 hydrogen when releasing its electrons becomes an ion with a charge of +1.

In addition, the literal aspect also measures students' ability to identify and describe chemical terms. Most students are categorized on a score of 1 (Figure 2), students can identify chemical terms contained in the text but have not provided a description of the terms. Only a small percentage of students were able to describe chemical terms and write their descriptions correctly in students who were grouped on scores 2 and 3. The difference between the two groups lies in the number of terms that can be identified and described appropriately. These findings show that most students understand the meaning of the text.

3.2 Interpretation aspect

The interpretation aspect plays a role in establishing the meaning of what is expressed in the text, which includes the explanation of concepts and the interpretation of chemical representations. The terminology of explaining chemical concepts in this study is a reasonable explanation of a phenomenon/concept, based on scientific facts, and forming a relationship based on evidence and logical reasoning (Berland & Reiser, 2009; Osborne & Patterson, 2011) this study, the explanation of the concept focuses on chemistry. To find out students' ability to explain chemical concepts, students are given open-ended. Question number 3 in each text, for example in one of the question items "Why can the ocean buffer system be damaged due to increased release of CO_2 gas in the atmosphere due to anthropogenic activities?". The results of the students' answers showed that most students who explained chemical concepts were still at the prestructural level (more than 60% of students). At the prestructural level, students explain chemical concepts with irrelevant explanations. Based on students' answers, it is known that most students are categorized into the structural group (Figure 3).

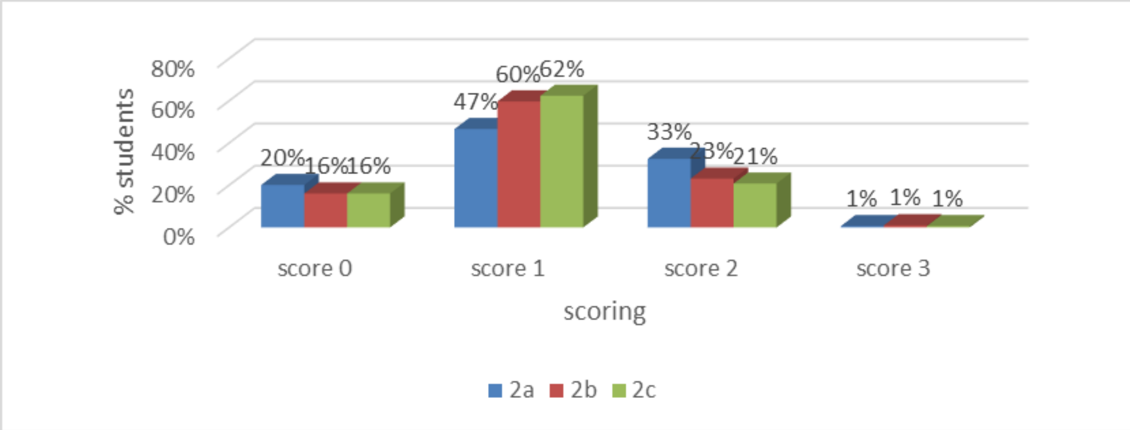


Figure 3. Scoring literation aspect – chemical terms

Here's an example of a student's answer (Tiana).

"Due to the imbalance of the existing order due to excess CO_2 gas from anthropogenic activities."

The second answer group is the unstructured group of students. Usually in uni-structural groups students can elaborate on one aspect and make clear relationships based on data or knowledge possessed. Here is an example of a student's answer (Nata),

"*Because the buffer system will be damaged if the addition of excess acid or base. If humans continue to use the combustion process to support their needs in large quantities, resulting in a large and uncontrolled release of CO_2 gas, which will have an impact on the ocean buffer system. Because the more CO_2 dissolves, the more H+ ions are released, so the ocean cannot maintain its pH*."

Based on the answers of Nata students, it is known that students can describe one aspect, namely explaining the damage to the ocean buffer system, based on the qualitative identification of factors that influence it. In the buffer solution concept, the addition of an excess concentration of a substance can result in the solution no longer being able to maintain its pH, which can be shown through changes in the pH of the solution that are increasingly acidic or alkaline.

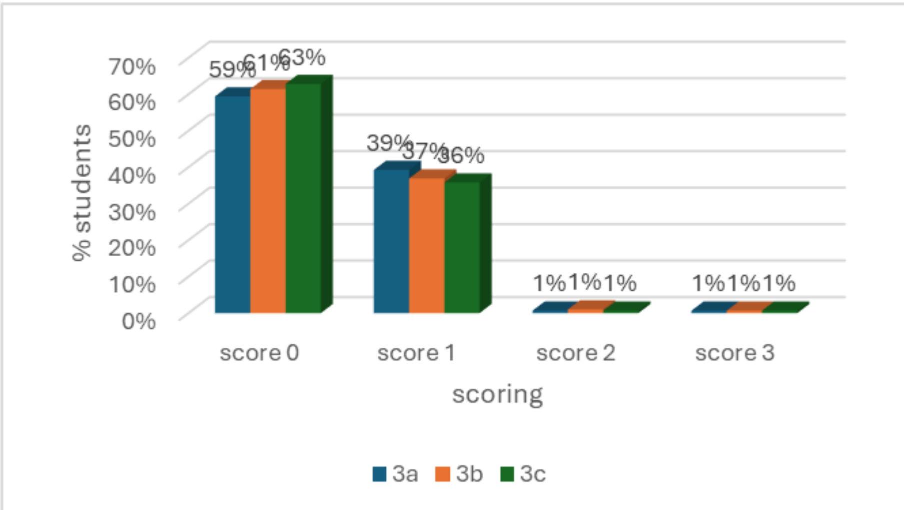


Figure 4. Scoring interpretation aspect – scientific explanation

The third answer group, namely the Multi structural student group, sample student answers (Name),

> "*Naturally, the ocean has a pH-maintaining capacity known as a buffer system. The buffer system occurs after CO_2 gas is dissolved in the ocean. However, this buffer system can be damaged if the release of carbon dioxide (CO_2) gas because of anthropogenic activities is not controlled so that the concentration of dissolved carbon dioxide (CO_2) gas exceeds the capacity of the ocean to maintain pH, so the ocean is more acidic because it forms more and more weakly acidic H_2CO_3. Reaction equation: $CO_2\ (aq) + H_2O \leftrightharpoons H_2CO_3$*".

Based on students' answers, it is known that students can describe three independent aspects, namely 1) students describe the definition of buffer solution as justification; 2) students stated that the phenomenon of increasing excess CO_2 gas concentrations can damage the ocean buffer system qualitatively; 3) students state the nature of H_2CO_3 (weak acid).

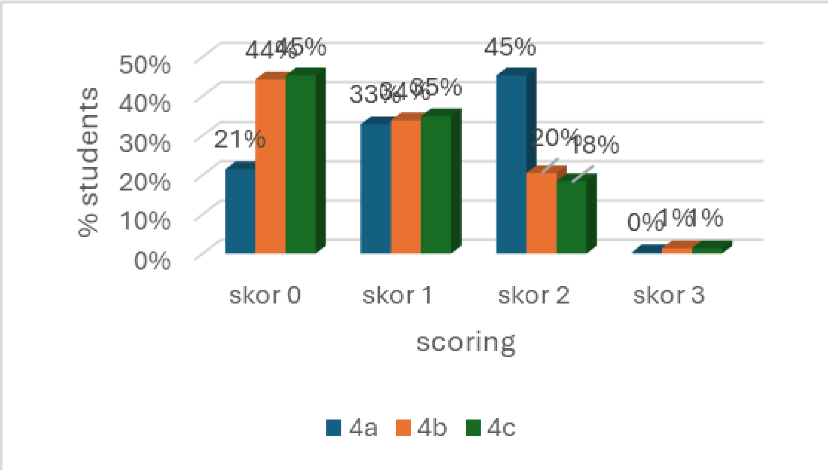


Figure 5. scoring interpretation aspect – chemistry representation

The highest group a student can reach is the relational group. In this group, students can understand the relationship between aspects to build a broader explanation. Sample student answer (Samara),

> "*The average pH of the ocean is 8.1. If CO_2 gas produced from anthropogenic activities increases the concentration of CO_2 gas dissolved in the ocean increases and forms weak acid H_2CO_3 which then dissociates into H+ and HCO_3^- the more it dissolves, the more H+ ions are released. So, the ocean is getting more acidic, or the pH drops. This decrease in pH is a sign of damage to the ocean buffer system. The reaction equation:*

$$CO_2\ (atom) \leftrightharpoons CO_2\ (aq)\quad (i)$$

$$CO_2\ (aq) + H_2O \leftrightharpoons H_2CO_3\quad (ii)$$

$$H_2CO_3 \leftrightharpoons H^+ + HCO_3^-\ (iii).\text{"}$$

Based on students' answers, it is known that students can describe the relationship between aspects to explain the damage to the ocean buffer system qualitatively, namely how students describe the natural properties of the ocean and then state the phenomenon of increasing CO2 gas and explain how the phenomenon of increasing ocean can affect pH. The explanation given by students in this group already has coherence between aspects. The findings in this study show that there are still many students categorized in prestructural groups as a reflection of the unaccustomed students building an understanding of chemistry through texts or students who tend to understand chemistry through rote memorization methods and mathematical calculations in chemistry.

The second aspect of interpretation is the interpretation of chemical representations. Interpretation of chemical representations is a student's interpretation of text communication that presents or applies chemical representations. To find out, students are given open-ended questions that lead students to be able to describe their understanding of chemical representations in the text.

The group of students who scored 0 did not provide answers relevant to chemical representations of the question.

"Describe what you know about chemical representations based on chemical representations presented from the text under the title Should we care about CO2 emissions? (prompt: Chemical representation: description of chemical concepts in various forms of modeling, such as a description of a chemical phenomenon that can be captured by the five senses, molecular explanations, and/or symbols).".

However, the group of students who scored 1, tended to give a single answer (one chemical representation), and most students answered those related to macroscopic representations. Sample student answer (Nata),

"A description of a chemical phenomenon that can be perceived through the five senses. The average pH of the ocean is 8.1 so the ocean tends to be alkaline. Scientists predict that if the release of CO_2 gas cannot be controlled then the ocean will continue to experience a decrease in pH, even by the middle of the 21st century it can reach a pH of 7.8. Because pH can be measured with litmus or acid-base indicators, and we can see.".

Furthermore, in interviews, students show that they do not understand and recognize chemical representations. However, in the questions, help is given so that students estimate the answer based on the chemical knowledge they have. Here's an excerpt of the interview

"I don't know what macroscopic, submicroscopic, and symbolic are, but I answer that because I've practiced acid-base solutions in the lab, what they use... litmus paper and what.. pp mo continue we can know the pH. "Well, because in that reading the pH of the ocean appears (pointing to paragraph 1) so I think ooh maybe this is the intention of the prompt in the problem (a description of a chemical phenomenon that can be captured through the five senses)".

For students who scored 2 and 3, the answers given were a combination of two or more chemical representations. An example of the answer of one of the students (Samara) (score 3) is below

"Chemical representation: An overview of a chemical phenomenon that can be captured through the five senses: The average pH of ocean is 8.1 so ocean tends to be alkaline. Because we can know the pH after measuring with litmus paper or pp, mo, blue bromtimol, or universal indicators. Symbols: CO_2 gas;H_2CO_3; (HCO_3^-); $CO_2 + H_2O \leftrightharpoons H_2CO_3 \leftrightharpoons H^+ + HCO_3^- \leftrightharpoons H^+ + CO_3^{2-}$; Ca^{2+}; CO_3^{2-}; $CaCO_3$ Symbols in chemistry Molecular explanation: Figure 1 in the image text of the process of acidification of ocean (here is the picture referred to by the student's answer). The image on the text tells the process of acidification of the ocean continues there is a picture of a colorful ball depicting the reacting compound. Ball colored 2 blue and 1 green, namely carbon dioxide gas in the air then reacts with the ocean (2 red and 1 blue colored balls form H_2CO_3 which is depicted 4 blue balls, 2 red balls, and 1 green ball because H2CO3 is a weak acid it releases H^+ ions which are described as red balls released from HCO_3 ions - then H^+ ions are released again so that more H^+ ions are released the more acidic in the ocean ".

The results of interviews with students stated that students could answer questions because there was a prompt given in the questions, so students combined previous knowledge and experience to build an understanding of chemical representations. Here's an excerpt from an interview with a student (Samara) "I don't know chemical representations (macroscopic, submicroscopic, and symbolic terms are also unfamiliar) because in the classroom (the learning process) is never taught. Oh... If our symbols are taught but don't know they are chemical representations, we only know that they are written that way, yes, symbols. But because there was a prompt in that question, I answered that. I just understood about the picture of a chemical phenomenon that can be captured through the five senses, macroscopic representation, molecular (submicroscopic) explanation, and symbols are representations (chemical representations) yes from here (during the interview process)". The findings in this study suggest that students are trying to build an explanation of the understanding of the application of chemical representations in texts through the help provided in the problem with previous knowledge and experience.

3.3 Application aspect

The application aspect is a function of using the knowledge and skills that students have gained through the reading process, to then be able to use them in new situations or solve a problem. The emphasis on this aspect of the application is on how students can use their knowledge to analyze and construct written ideas (written arguments). Here is one of the students' answers in giving ideas related to "What ideas can you give as a form of contribution to the issue of ocean acidification?" Give arguments based on chemical knowledge that you understand.". Most of the students' answers are categorized in the group that gets a score of 0 (Figure 5) in this group students have not provided relevant arguments. Sample student answer

"In my opinion, we must maintain the balance of the environment." (Tiana).

This is different from students in score group 1. Students can submit ideas only in the form of claims or consist of one component of an argument so that the argument is very weak. This is because there is no data or warrant to support his claim. An example of the answer of the student in this group (Nata)

"I think it is necessary to add a base to the lake.".

In the score group 2 students can submit claims that are corroborated by data or warrants, for example, the answer given by students (Name)

"Ocean acidification is a decrease in the pH of ocean so that it is more acidic. As I know, to neutralize acids, bases are needed (claims). Based on the chemistry I studied, there is a neutralization reaction that is an acid and base reaction to produce a neutral solution (warrant)".

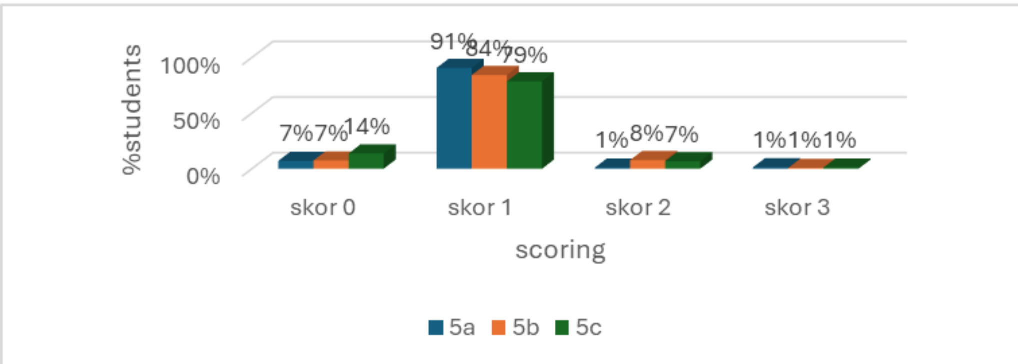


Figure 5. scoring application aspect – argumentation

In the student group score 3 students can propose ideas by meeting the criteria of three or more argument components in the arrangement (the arrangement of ideas submitted by students consists of claims supported by data, warrants, or backing and contradictions (rebuttals)). Here is the student's answer (Samara)

"In my opinion, according to the chemical knowledge I have, the issue of ocean acidification is that the ocean becomes more acidic so the solution can be solved by adding bases (claims). According to the chemical material I got, if we add a base solution to the acid solution, a neutralization reaction will occur, and the solution becomes neutral (justification/warrant). What makes the ocean acidic is due to excessive CO_2 *gas emissions dissolved in the sea and formed* H_2CO_3 *which dissociates into* H^+ *and* CO_3^{2-} *so that the buffer system in the sea is disturbed because of the large number of* H^+ *ions released. To balance the H+ ion it is necessary to add* OH^- *ions to be neutral. From the Arrhenius acid-base theory,* H^+ *ions indicate acids, and* OH^- *ions indicate bases (backing). The solution adds the base Ca* $(OH)_2$*. The reaction equation is* $H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$ *(data). But, if you think about it again, adding a base can neutralize because the ocean is vast, there continue to be other consequences on the environment, or it doesn't also need to be a concern (contradiction).*

Discussion

Reading skills are vital for learning science and preparing for the future (Norris & Phillips, 2003). Science texts, especially in chemistry, differ from fictional texts in syntax, language, and cognitive demands (Carnine & Carnine, 2004; Fang, 2005). This research investigates reading skills specifically in chemistry using informational texts relevant to socioscientific and chemical issues. For instance, one text, "Should we care about CO2 emissions?" discusses CO2 emissions and ocean acidification. Most students could identify the main chemical ideas and terms, but they need instruction to understand the significance of chemical terminology (Song & Carheden, 2014; Meyer & Pietzer, 2022). Improving chemistry understanding requires reading tactics like note-taking, highlighting, and creating glossaries. For interpreting information, the study used SOLO Taxonomy (Biggs & Collis, 1982) to evaluate students' explanations of chemical concepts and phenomena. The SOLO Taxonomy identifies five levels of learning complexity: prestructural, uni-structural, multi-structural, relational, and extended abstract (Zou et al., 2014). In this study, four levels were observed, with over 50% of students in the prestructural group, providing irrelevant explanations for chemical concepts and phenomena.

The second largest group of students, less than 30%, falls into the uni-structural category, with the rest in the multi-structural and relational categories. Many students struggle to provide coherent explanations of chemical topics, indicating potential gaps in understanding. Previous research shows students often can't accurately define terms (Sheppard, 2006) or grasp different concepts like dissociation and ionization (Calatayud et al., 2007). They also struggle with distinguishing and transferring between chemical representations (Al-Balushi, 2013; Smith & Metz, 1996). In this study, students scoring 1 could interpret one chemical representation, those scoring 2 could interpret two, and those scoring 3 could interpret all three. However, most students scored 0, unable to interpret any representations. This suggests students need to develop reading skills to understand implied information, particularly explanations and interpretations. Previous studies support this, indicating that difficulties in understanding chemistry stem from an inability to interpret and relate different representations (Gabel, 1999; Gilbert & Treagust, 2009; Rahayu & Kita, 2010). Comprehensive prior knowledge of chemistry can aid in understanding texts (Abdelaal & Sase, 2014; Ozuru et al., 2009; Taboada & Guthrie, 2006).

The application aspect assesses students' ability to connect text information with their experiences or prior knowledge. This includes forming written ideas or arguments, focusing on the alignment of ideas with chemical knowledge and the structure of arguments. An argument structure includes claims, data, justifications, support, and rebuttals. The study found that most students can present weak written ideas, consisting mostly of claims without supporting data or justifications. Over 50% of students only made claims. A few students could provide data-supported arguments. This indicates difficulty in constructing well-structured arguments, often due to a lack of knowledge about argumentation. Students tend to base arguments on personal values or experiences rather than scientific knowledge (Chang & Chiu, 2008). This difficulty is likely due to insufficient training in argumentation skills. Explicit instruction in argumentation can improve these skills (Astarina et al., 2019; Saija et al., 2023; Setyaningsih et al., 2019). High school students in this study, despite having sufficient chemistry knowledge, struggled with argumentation due to unfamiliarity with argumentation concepts.

The findings suggest that while students can understand explicit text information, they need practice and supportive learning to grasp implicit information, which is crucial for scientific literacy (Norris & Phillips, 2003). Further research with a broader sample is needed to generalize these findings and understand students' thinking patterns. Enhancing students' proficiency in understanding chemical terminology and texts will improve their comprehension and argumentation skills. Incorporating reading interventions in chemistry education can enhance reading literacy, closely linked to scientific reasoning (Fang & Wei, 2010). Providing time, opportunities to practice reading strategies, and motivation to make reading a habit are essential. A love for reading will motivate students to explore complex chemistry topics, improve understanding, and enhance argumentation skills. Future research should develop chemistry learning models and strategies aimed at improving reading skills and chemistry concepts.

4. CONCLUSION

Researchers created a chemistry text reading skills tool to evaluate students' comprehension of chemistry concepts and their capacity to read science literature. The instrument included three chemistry texts and five essay questions, demonstrating a significant association ($r = 0.918$) between text comprehension abilities and grasp of chemical principles. Most students have difficulty comprehending the primary chemical concepts in the book, can recognize but not articulate chemical words accurately, and are at a basic level in elucidating chemical concepts. Moreover, many students find it challenging to generate innovative ideas or arguments as resolutions to issues presented in chemical literature. The study emphasizes the need of assisting students in enhancing their reading abilities, particularly in comprehending intricate texts such as scientific literature, and proposes a wider demographic analysis to apply the results more broadly. The study was limited by the use of Google Forms, which may have impeded proper assessment, particularly in activities that used sub-script or superscript. Future research could focus on developing targeted interventions to improve students' ability to describe chemical terms accurately and enhance their skills in developing creative solutions to problems presented in chemistry texts. For example, by providing a text at the beginning of learning, students are asked to make a list of chemical terms used in the text and define them, and are given inquiry questions related to the text to help students build their knowledge.

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