Journal of Learning Improvement and Lesson Study
Volume 5 Number 1 2025, pp, 1-13
E-ISSN: 2798-9011
DOI: 10.24036/jlils.v5i1.137
Received March 4, 2025; Revised May 21, 2025; Accepted June 3, 2025
Availaible Online: https://jlils.ppj.unp.ac.id/index.php/

Discovering the Depths of Scientific Literacy: Evaluating XI-Grade Student Progress Using Bybee's Definition

Putri Permatasari[1]*, Zonalia Fitriza[2]

[1]Department of Materials Science and Processing, Gifu University, Gifu 501-1113, Japan
[2]Department of Chemistry, Padang State University, Padang 25131, Indonesia
*Corresponding author, e-mail: putri.permatasari.s4@s.gifu-u.ac.jp

Abstract
This study evaluates the scientific literacy of XI-grade students in understanding science and technology concepts amid rapid technological advances. Scientific literacy is the ability to apply learned concepts to real-world phenomena. A cluster random sampling of 30 students was assessed using a reasoned multiple-choice test. Results showed very inadequate scientific literacy, with an average accuracy of 33.167%. Further analysis then classified the students as illiterate, nominally literate, as functionally literate, and as conceptually literate according to Bybee category. These findings highlight the need for improved teaching strategies that emphasize contextual learning and real-world applications to enhance students' scientific literacy.

Keywords: Scientific literacy, Bybee's level, student misconceptions, science education, two-tier diagnostic test.

Introduction

The development of technology in the Industrial Revolution 4.0 era has brought major changes in various aspects of life, including in the fields of education and science (Agustina et al., 2024). In facing increasingly complex global challenges, individuals are expected to have good scientific literacy in order to be able to understand, evaluate, and apply scientific concepts in everyday life (Howell & Brossard, 2021; Li & Guo, 2021; Tuttle et al., 2023; Wahab et al., 2025). Scientific literacy is not only limited to the ability to read and understand scientific texts, but also includes the ability to think critically, solve problems, and make decisions based on in-depth scientific understanding (Bramastia & Rahayu, 2023; Dawson et al., 2024; Pasternak Taschner & Almeida, 2024). According to UNESCO (2019), literacy is a basic skill that includes the ability to read, write, understand, and communicate information in various forms (Zua, 2021). Scientific literacy, as one aspect of literacy, reflects an individual's ability to connect scientific concepts with phenomena that occur around them (Lopes et al., 2024; Permatasari & Fitriza, 2019). Bybee (1997) classifies the level of scientific literacy into five categories, namely: (1) illiteracy (not understanding scientific concepts at all), (2) nominal literacy (having limited understanding and often wrong), (3) functional literacy (able to identify and apply scientific concepts simply), (4) conceptual literacy (understanding scientific concepts correctly and using them in various contexts), and (5) multidimensional literacy (connecting scientific concepts with other disciplines and using them in analyzing more complex problems) (Aquino et al., 2025; Cerna et al., 2021; Costa et al., 2021; Shahzadi & Nasreen, 2020; Soobard & Rannikmäe, 2011).

In Indonesia, the results of the PISA assessment show that students' scientific literacy skills are still at a low level compared to other countries (Hamidah et al., 2025; Mujakir et al., 2024; Yusmaita & Nasra, 2017). This low scientific literacy has implications for students' lack of understanding of the scientific concepts taught in schools, including in chemistry (Khoiriza et al., 2021; Prasetya & Maisarah, 2024; Rahmawati et al., 2024; Wiyarsi et al., 2021). One of the content in chemistry that is often a challenge for students is buffer solutions (Habiddin et al., 2024; "Implementation of Virtual Laboratory Platform to Study Human Buffer Solutions in the Era of COVID-19," 2020; Lestari & Atun, 2021; Salame et al., 2022). This material requires not only a strong conceptual understanding but also the ability to connect theory with its application in real life, such as in biological and industrial systems (Irwanto et al., 2024; Sehasari Dewi & Mulyani, 2024).

Student ability has been widely researched, but most of them use indicators that vary, making it difficult to compare between studies. Research that measures student ability with a definite standard, such as Bybee's 5E Learning Cycle, is still rare. In fact, the use of standards such as Bybee's allows for more objective, measurable, and comparable results across studies. Therefore, this study was developed by applying Bybee's standards consistently to produce more valid data and support evidence-based education evaluation.

This study aims to analyze the level of scientific literacy of grade XI students in understanding the material of buffer solutions based on the Bybee scientific literacy classification (Aquino et al., 2025b; Gormally et al., 2012; Kumalasari & Suyono, 2023; Muntholib et al., 2023; Yudha et al., 2023). By using a diagnostic test instrument in the form of two-tier multiple-choice with open reasoning, this study attempts to identify the extent to which students understand the concept of buffer solutions and the extent to which they are able to relate it to scientific phenomena in everyday life (Haryani et al., 2023; Yudha et al., 2023). The results of this study are expected to provide a clearer picture of the level of scientific literacy of students and become the basis for designing more effective learning strategies to improve the quality of scientific understanding among students.

Method

This study was a descriptive qualitative study that aimed to describe the scientific literacy skills of students in buffer solution material. The study included all 11th-grade science students at MAN 2, Padang province, Indonesia. The sample for this study was one class of 30 11th-grade science students, selected using a cluster random sampling technique. The researchers, Woro Sumarni, Hesti Widya Prasida, and Sri Susilogati Sumarti, developed a scientific literacy test question sheet consisting of multiple-choice questions for this study (Sumarni et al., 2017). The assessment instrument was validated by experts and declared valid. The test's reliability was calculated using the KR-20 formula and yielded a result of 0.7951. The students were given a 30-question multiple-choice test representing 19 learning indicators in the buffer solution material. They had two hours of class time to complete the test (2 x 45 minutes).

The researchers calculated the overall achievement of scientific literacy skills by using the average percentage of students who correctly answered each question in the scientific literacy test.

$$\textit{Student achievement per question} = \frac{\textit{total student achievement on question X}}{\textit{student's maximum achievement}} \times 100\% \qquad 1$$

We calculated the overall achievement of scientific literacy skills by determining the average percentage of students who answered each question correctly. To calculate this percentage, we divided the total achievement obtained by students on each question by the maximum student achievement possible for that question (60 points) if every student answered that question perfectly. This equation compared students' achievements on each question to the maximum score and presented it as a percentage. Finally, we obtained each student's scientific literacy result by using equation 2.

$$\textit{Science literacy} = \frac{\sum \textit{student achievement per question}}{\textit{number of questions}} \qquad 2$$

Furthermore, we interpreted the data on our students' scientific literacy using the criteria that we listed in the table 1 (Wulandari & Wulandari, 2016). We used the classification by Salirawati (2011) to connect Bybee's level of scientific literacy with the scientific literacy questions (Salirawati, 2013). This was done by categorizing students' answers to two-tier questions. The classification of student responses is presented in the table 2. Table 3 shows the criteria for each level of scientific literacy (Shwartz et al., 2006).

Table 1. Criteria for scientific literacy ability

Criteria	Percentage (%)
Excellent	80-100
Good	66-79
Sufficient	56-65
Insufficient	40-55
Very Inadequate	30-39

Table 2. Types of Test Responses in Two Tiers

No.	Student Answer Pattern	Understanding level category	Science literacy level
1.	correct answer-correct reason	Understand	Conceptual literacy Functional literacy
2.	correct answer-wrong reason	Misconception	Nominal literacy
3.	wrong answer-correct reason		
4.	wrong answer-wrong reason	Do not understand	Illiteracy

Table 3. Table of scientific literacy levels

Science literacy level	Criteria
Illiteracy	Students cannot respond to scientific questions
Nominal literacy	Students can respond to scientific questions but experience misconceptions
Functional literacy	Students can respond to scientific questions with limited answers
Conceptual literacy	Students can respond well to scientific questions and relate concepts in science
Multidimensional literacy	Students can respond and answer questions using scientific knowledge and knowledge outside science.

Results and Discussion

1. Students' overall scientific literacy

To determine the level of achievement of students' scientific literacy, the percentage of correct answers on each question was calculated by comparing the score obtained with the optimal maximum score of 60, then converted into a percentage by multiplying the result by 100%. The data obtained were then classified based on the level of student understanding shown through their responses to the two-tier questions. The level of student understanding was determined based on the characteristics of their scientific literacy level. Overall, scientific literacy achievement was calculated by finding the average percentage of correct answers from all questions tested.

The results showed that students' scientific literacy achievement in the cognitive aspect was classified as "very low," with an average achievement of 33.167%. Of the total 30 questions tested, 18 questions had a success rate of between 40-50%, two questions had a success rate of 30-39%, while the other ten questions had a success rate of less than 30%. This shows that most students have significant difficulty in understanding the concepts being tested.

The low achievement of science literacy indicates that students do not have the knowledge and skills needed to actively participate in modern society. Scientific literacy includes the ability to apply scientific knowledge in everyday life. Therefore, low achievement levels reflect a lack of conceptual understanding, high-level thinking skills, problem-solving abilities, and understanding of the nature of science.

There is a relationship between the various dimensions of scientific literacy, where low scientific literacy in one aspect can have an impact on other aspects. For example, inadequate understanding of scientific concepts can hinder students' ability to apply science in real life and understand the related context. Therefore, scientific literacy teaching must be applied in learning activities that encourage students to explain phenomena scientifically, solve problems using chemical understanding, and analyze the benefits of chemical applications.

Students' low science literacy is the result of various interrelated factors, especially related to teaching methodology, curriculum design, and teacher readiness. Many teaching approaches still emphasize memorization over experiential learning, so students only gain a superficial understanding of scientific principles (Anshar et al., 2023). The lack of engaging instructional media also contributes to students' interest and understanding of science. In terms of curriculum, the limited focus on scientific literacy and the lack of integration of local cultural contexts cause learning materials to feel less relevant and difficult to apply in real life (Dewi et al., 2019). In addition, teachers' low science literacy and lack of professional training in science literacy-based learning strategies limit their ability to develop students' critical and scientific thinking skills (Permatasari & Fitriza, 2019; Wahyuni & Silfianah, 2024). Limited learning time in schools is also an obstacle in exploring material in depth through experiments and discussions (OECD, 2019). On the other hand, external factors such as socioeconomic status and access to learning resources can also affect students' science literacy skills, because they affect the learning opportunities and support, they receive.

One effective way to improve scientific literacy is to connect learning materials to everyday life. Previous research findings also show that the achievement of the three main aspects of scientific literacy—content, context, and competence—tends to be in the "very low" category (Permatasari & Fitriza, 2019). Therefore, scientific literacy skills must be an integral part of the learning process, so that students are accustomed to providing scientific explanations for phenomena, using chemical understanding to solve problems, and evaluating the benefits of chemical applications in real life.

∑ Achievements	=	995 %
∑ Question	=	30
Average achievement of scientific literacy	=	33,167 %

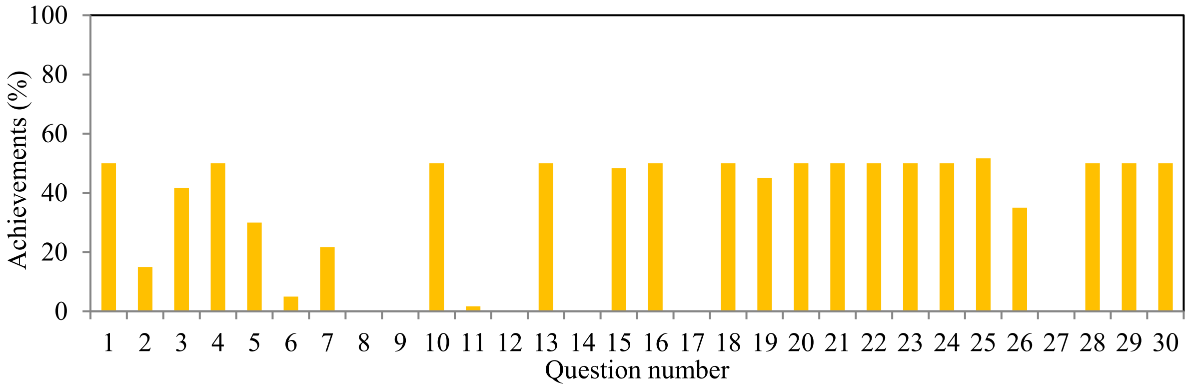


Figure 1. Achievement of students' scientific literacy per question

2. Student Science Literacy at the Bybee Level

Data collection on students' scientific literacy skills was carried out by analyzing their level of understanding of the concepts being tested. According to Salirawati (2011) (Salirawati, 2013), the level of student understanding can be obtained by analyzing the results of diagnostic tests and classifying students' answers to two-tier questions. Based on the results of the study, of the 30 questions tested on 30 students, 34.35% of students were categorized as not understanding the concept, 65.1% had misconceptions, and only 0.55% really understood the concept being tested. In other words, the majority of students had difficulty answering scientific literacy questions correctly. Of all the participants, only three students were able to answer the two-tier questions correctly, both in terms of answer choices and the reasons given. In detail, student number 5 answered one question correctly, student number 9 answered two questions correctly, and student number 10 also answered two questions correctly. Table 5 presents the overall percentage of student understanding.

Furthermore, students' scientific literacy achievements were analyzed based on the levels of scientific literacy proposed by Bybee (1997) (R. Bybee et al., 2009; R. W. Bybee, 1997). From the test results consisting of 30 questions worked on by 30 students, it is known that 34.35% of students are at the basic literacy level (illiteracy), which indicates that they do not understand the scientific concepts being tested. As many as 64.88% of students are included in the nominal literacy category, which means they recognize scientific concepts but have a wrong understanding or misconception. Only 0.22% of students reach the functional literacy level, where they are able to identify and apply concepts in a limited way. Meanwhile, only 0.33% of students reach the conceptual literacy level, which indicates that they can understand and connect scientific concepts correctly in various contexts. These results indicate that most students still have difficulty in understanding and applying scientific concepts in depth. Based on the scientific literacy question instrument used, the highest level of understanding that can be measured in this study is conceptual literacy. At this level, students are expected to be able to use chemical understanding to explain phenomena or understand a concept correctly. Conceptual literacy also includes procedural skills as well as an understanding of scientific inquiry methods and technological design . However, the test instruments in this study were not able to measure the level of multidimensional literacy, which requires students to connect their understanding of chemistry with other disciplines or with knowledge outside the field of chemistry (Shwartz et al., 2006).

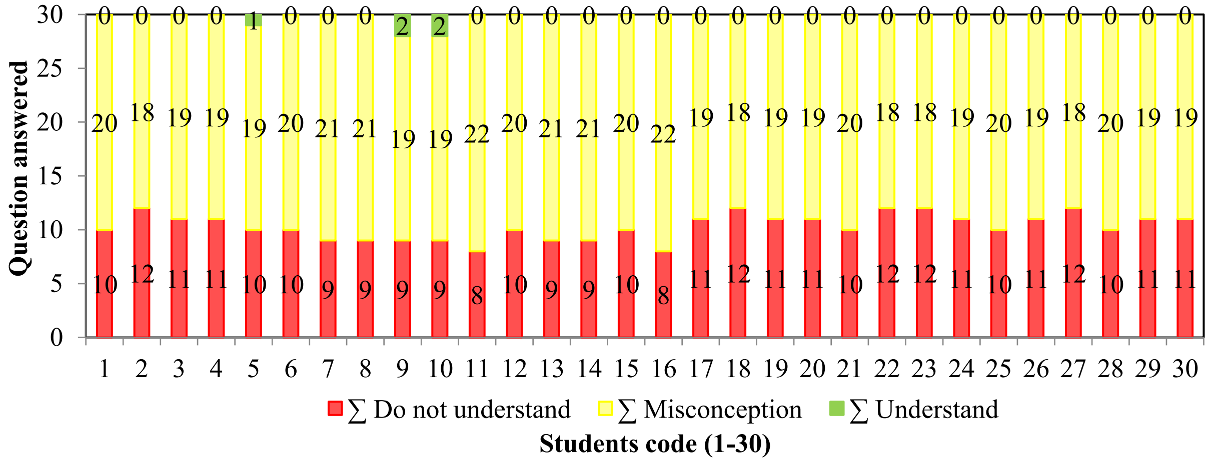


Figure 2. The number of questions that are understood, misconceptions, and not understood by students based on the 30 questions tested

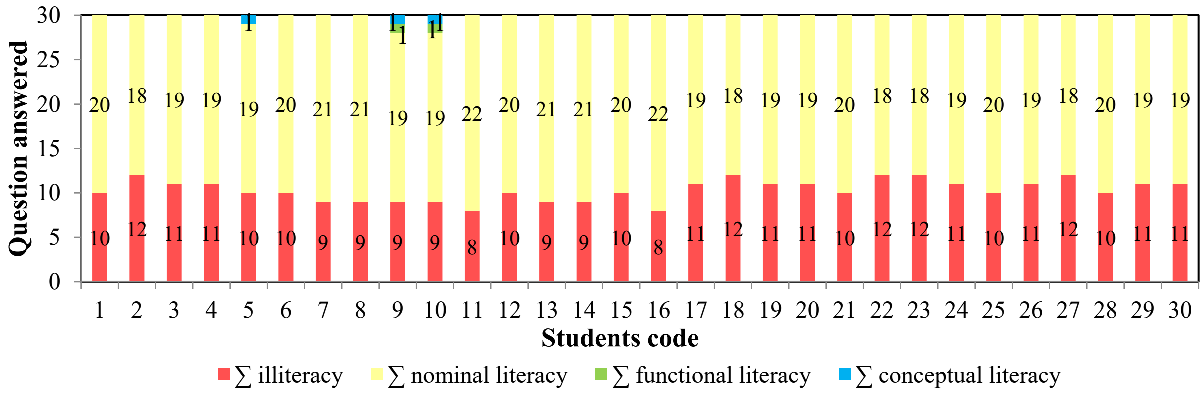


Figure 3. Student achievement at the level of scientific literacy (per question)

2.1. Illiteracy

Unanswered questions and incorrect answers fall into this category. Students at the basic literacy level (illiteracy) are unable to respond to scientific questions correctly. Based on the analysis results, the percentage of students at the basic literacy level reached 34.3%, indicating that they did not understand the concepts tested in the two-tier questions. This high percentage indicates that many students are unable to connect or respond to scientific questions well. In addition, they also experience limitations in terms of scientific vocabulary, conceptual understanding, context, and cognitive capacity to recognize and answer science questions correctly.

2.2 Nominal Literacy Level

Students who reach the nominal literacy level are able to respond to scientific questions, but still have misconceptions. In this category, students can choose the correct answer with the wrong reason or vice versa, choose the wrong answer but with the right reason. Based on the analysis, the percentage of students at the nominal literacy level reached 65.1%, which shows that the majority of students experience misconceptions when working on two-tier problems. This high percentage indicates that although students can recognize scientific concepts, their understanding is still wrong or not entirely correct. In addition, these results also show that students have an initial understanding of a concept, but they have not fully understood its meaning in depth.

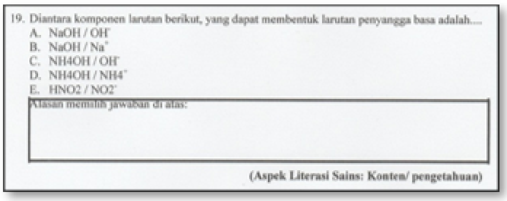
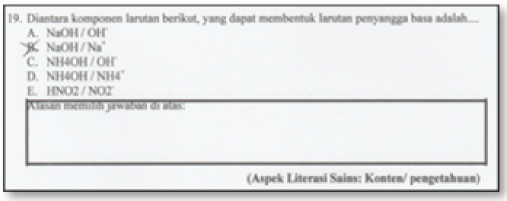
in the original language of the question (Indonesian)	English translation
 19. Diantara komponen larutan berikut, yang dapat membentuk larutan penyangga basa adalah.... A. NaOH / OH- B. NaOH / Na+ C. NH4OH / OH- D. NH4OH / NH4+ E. HNO2 / NO2- Alasan memilih jawaban di atas: (Aspek Literasi Sains: Konten/ pengetahuan)  19. Diantara komponen larutan berikut, yang dapat membentuk larutan penyangga basa adalah.... A. NaOH / OH- B. NaOH / Na+ C. NH4OH / OH- D. NH4OH / NH4+ E. HNO2 / NO2- Alasan memilih jawaban di atas: (Aspek Literasi Sains: Konten/ pengetahuan)	19. Which of the following components of a solution can form a basic buffer solution? A. $NaOH/OH^-$ ~~B~~. $NaOH/Na^+$ C. NH_4OH/ OH^- D. NH_4OH/ NH_4^+ E. HNO_2/NO^{2-} Reasons for choosing the answer above: ....
Kunci jawaban: D. NH4OH adalah basa lemah dan NH_4^+ adalah asam konjugasinya, sehingga kedua komponen tersebut dapat membentuk larutan penyangga basa	Answer key: D. NH4OH is a weak base and NH_4^+ is its conjugate acid, so that the two components can form a basic buffer solution

Figure 4. Student's answer to question number 19

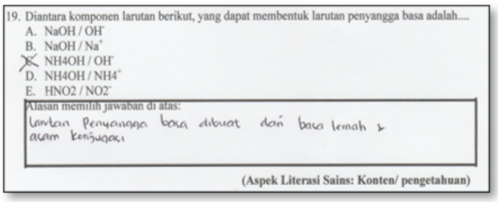
in the original language of the question (Indonesian)	English translation
 19. Diantara komponen larutan berikut, yang dapat membentuk larutan penyangga basa adalah.... A. NaOH / OH- B. NaOH / Na+ C. NH4OH / OH- D. NH4OH / NH4+ E. HNO2 / NO2- Alasan memilih jawaban di atas: larutan Penyangga basa dibuat dari basa lemah & asam konjugasi (Aspek Literasi Sains: Konten/ pengetahuan) Larutan penyangga basa dibuat dari basa lewah dan asam konjugasi	19. Which of the following components of a solution can form a basic buffer solution? A. $NaOH/OH^-$ B. $NaOH/Na^+$ ~~C~~. NH_4OH/ OH^- D. NH_4OH/ NH_4^+ E. HNO_2/NO^{2-} Reasons for choosing the answer above: Basic buffer solutions are made from a weak base and a conjugate acid
D. NH_4OH adalah basa lemah dan NH_4^+ adalah asam konjugasinya, sehingga kedua komponen tersebut dapat membentuk larutan penyangga basa	D. NH4OH is a weak base and NH_4^+ is its conjugate acid, so that the two components can form a basic buffer solution

Figure 5. student's answer to question number 19

2.3 Functional Literacy Level

Functional Literacy is the level at which students can describe a concept correctly, but their understanding is still limited. At this level, students can recall basic scientific knowledge and use that knowledge to describe or evaluate a conclusion, although still within a limited scope.

Based on the test results, only two student answers were categorized as partially understood, both from question number one. Students are considered to only partially understand the concept if their multiple-choice answers are correct and the reasons given are also correct, but the explanation given is incomplete.

For example, in question number one, the correct answer key is D, with the reason that the initial pH measurement was taken after the drink was no longer foamy. This is because the presence of foam indicates that the carbonic acid in the drink has broken down into CO_2 and H_2O. If left until the foam disappears, the CO_2 in the drink will evaporate into the air, leaving only H_2O. Thus, the disappearance of the foam indicates that only phosphate buffer solution remains in the soda.

The answers from the two students in this category indicate that they understand most of the concepts tested, but are unable to provide a fully complete explanation of the phenomena that occur.

Based on the answers given, it can be seen that the students understand that pH measurements are taken after the foam in the soda disappears and that the pH will change. However, they do not understand the reason behind the phenomenon, namely how the presence or disappearance of foam can affect pH. Therefore, the students' answers are categorized as functional literacy, because they have not been able to connect the concept to the underlying chemical principles.

Based on the analysis, the percentage of students who achieved the functional literacy level was only 0.23%, indicating that most students are still unable to integrate scientific explanations at the molecular and macromolecular levels. They are also not yet accustomed to using chemical language, such as symbols or molecular representations, in explaining the phenomena that occur.

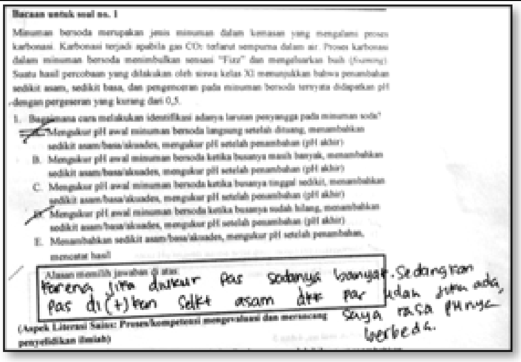
in the original language of the question (Indonesian)	English translation
 **Bacaan untuk soal no. 1** Minuman bersoda merupakan jenis minuman dalam kemasan yang mengalami proses karbonasi. Karbonasi terjadi apabila gas CO_2 terlarut sempurna dalam air. Proses karbonasi dalam minuman bersoda menimbulkan sensasi "Fizz" dan mengeluarkan buih (foaming). Suatu hasil percobaan yang dilakukan oleh siswa kelas XI menunjukkan bahwa penambahan sedikit asam, sedikit basa, dan pengenceran pada minuman bersoda ternyata didapatkan pH dengan pergeseran yang kurang dari 0,5. 1. Bagaimana cara melakukan identifikasi adanya larutan penyangga pada minuman soda? A. Mengukur pH awal minuman bersoda langsung setelah dituang, menambahkan sedikit asam/basa/akuades, mengukur pH setelah penambahan (pH akhir) B. Mengukur pH awal minuman bersoda ketika busanya masih banyak, menambahkan sedikit asam/basa/akuades, mengukur pH setelah penambahan (pH akhir) C. Mengukur pH awal minuman bersoda ketika busanya tinggal sedikit, menambahkan sedikit asam/basa/akuades, mengukur pH setelah penambahan (pH akhir) D. Mengukur pH awal minuman bersoda ketika busanya sudah hilang, menambahkan sedikit asam/basa/akuades, mengukur pH setelah penambahan (pH akhir) E. Menambahkan sedikit asam/basa/akuades, mengukur pH setelah penambahan, mencatat hasil Alasan memilih jawaban di atas: karena jika diukur pas sodanya banyak. Sedangkan pas di(+)kan sdkt asam dkk pas udah ada, saya rasa pH nya berbeda. (Aspek Literasi Sains: Proses/kompetensi mengevaluasi dan merancang penyelidikan ilmiah)	Carbonated drinks are a type of packaged beverage that undergoes carbonation process. Carbonation occurs when CO2 gas dissolves completely in water. The carbonation process in carbonated drinks creates a sensation of "fizz" and produces foam. An experiment conducted by an 11th-grade student showed that adding a small amount of acid, base, or dilution to a carbonated drink resulted in a pH shift of less than 0.5. 1. How to identify the presence of a buffer solution in a soda drink? A. Measure the initial pH of the carbonated drink directly after pouring, add a small amount of acid/base/dilution, and measure the pH after the addition (final pH). B. Measure the initial pH of the carbonated drink when there is still a lot of foam, add a small amount of acid/base/dilution, and measure the pH after the addition (final pH). C. Measure the initial pH of the carbonated drink when there is only a little foam left, add a small amount of acid/base/dilution, and measure the pH after the addition (final pH). ~~D~~. Measure the initial pH of the carbonated drink when the foam has disappeared, add a small amount of acid/base/dilution, and measure the pH after the addition (final pH). E. Add a small amount of acid/base/dilution, measure the pH after the addition, and record the result. Reasons for choosing the answer above: because if you measure when there is a lot of foam, the results will be different.
D. Pengukuran pH awal dilakukan setelah minuman tidak berbusa, sebab adanya busa menunjukkan bahwa asam karbonat yang ada dalam minuman berubah menjadi CO2 dan H2O. Jika didiamkan sampai busanya hilang, maka CO2 dalam minuman sudah terlepas ke udara dan H2O tetap tinggal. Jadi, habisnya busa menunjukkan bahwa dalam minuman bersoda tersebut tinggal ada buffer fosfat.	D. pH measurement was conducted after the beverage lost its fizz, as the presence of bubbles indicates that the carbonic acid in the drink has converted into CO2 and H2O. If left until the bubbles disappear, then the CO2 in the drink has escaped into the air and only H2O remains. Therefore, the disappearance of bubbles indicates that the remaining components in the carbonated drink are phosphate buffers.

Figure 6. Students' answers to question number 1

2.4 Conceptual Literacy Level

Conceptual Literacy reflects students' ability to understand and relate key conceptual schemes to their general knowledge of science and procedural skills. At this level, students not only understand scientific concepts in depth but are also able to apply the process of scientific inquiry and technological design in problem solving. Students with higher scientific literacy will be able to create and use conceptual models to predict and explain phenomena, analyze scientific investigations, relate data as evidence, evaluate alternative explanations for the same phenomenon, and communicate conclusions appropriately.

The fundamental difference between functional and conceptual literacy lies in students' ability to use chemical characteristics in their explanations. Students with functional literacy understand chemical concepts but are not yet able to explain them using more specific chemical characteristics, such as molecular formulas or molecular structures. In contrast, students with conceptual literacy can explain concepts in more depth and integrate these chemical aspects into their solutions. This ability is very important in understanding scientific concepts holistically and applying them in various real situations.

In this study, only three student answers were classified as having conceptual understanding, namely in questions 6, 25, and 29. Students are considered to understand if their answers are in accordance with the answer key and the reasons given are correct and complete. In question number 6, students are asked to identify the main buffer system in the blood. The correct answer key is A, with the reason that "the buffer system in the blood consists of a pair of carbonic acid (H_2CO_3) and bicarbonate (HCO_3^-)". The students' answers are in accordance with the answer key, although with slight differences in wording, indicating that they understand the concept. In question number 25, students are asked to calculate the pH of a buffer solution. The students' answers that are in accordance with the answer key indicate that they understand the concept of calculation in buffer solution chemistry. In question number 29, students are asked to identify industrial products that contain buffer solutions. The students' answers state that "canned drinks and sprite contain buffer solutions", while the answer key states that buffer solutions are widely used in various everyday products, such as syrup, toothpaste, canned drinks, and soda. Although students only mentioned some examples, their answers were still considered correct because they were in accordance with the principles of the buffer solution concept. Based on calculations, the percentage of students who achieved conceptual literacy was only 0.33%, indicating that most students still have difficulty in applying chemical concepts correctly in everyday situations. This low score also indicates that science literacy questions still feel foreign to students, because the format and cognitive demands are different from the questions they usually encounter in class. Students are asked to connect their knowledge to everyday life contexts, which is a challenge in itself in improving their science literacy. In addition, the low level of conceptual literacy also reflects the lack of a learning approach that emphasizes the integration of concepts with real applications, which should be an important part of science learning. Therefore, innovation is needed in learning methods that are more oriented towards problem solving, concept-based discussions, and the use of models and simulations that can help students connect theory with its application in everyday life.

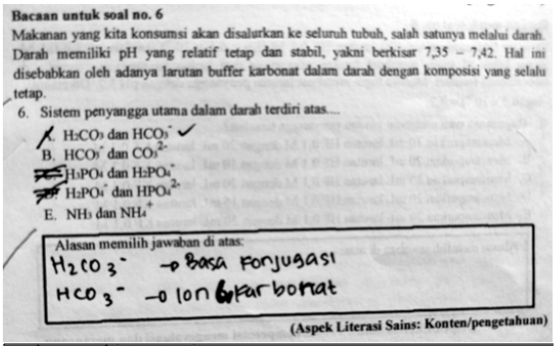
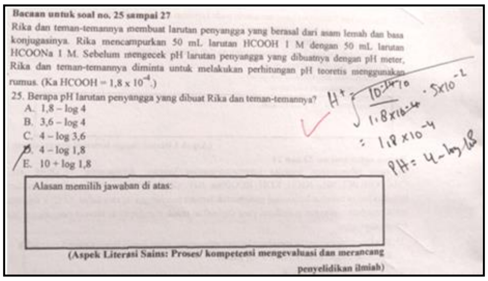
in the original language of the question (Indonesian)	English translation
 **Bacaan untuk soal no. 6** Makanan yang kita konsumsi akan disalurkan ke seluruh tubuh, salah satunya melalui darah. Darah memiliki pH yang relatif tetap dan stabil, yakni berkisar 7,35 – 7,42. Hal ini disebabkan oleh adanya larutan buffer karbonat dalam darah dengan komposisi yang selalu tetap. 6. Sistem penyangga utama dalam darah terdiri atas.... A. H_2CO_3 dan HCO_3^- B. HCO_3^- dan CO_3^{2-} C. H_3PO_4 dan $H_2PO_4^-$ D. $H_2PO_4^-$ dan HPO_4^{2-} E. NH_3 dan NH_4^+ Alasan memilih jawaban di atas: $H_2CO_3^-$ → Basa Konjugasi HCO_3^- → Ion bikarbonat **(Aspek Literasi Sains: Konten/pengetahuan)**	The food we consume is transported throughout our body, including through the blood. The blood has a relatively constant and stable pH, ranging from 7.35-7.42. This is due to the presence of a constant composition of carbonate buffer solution in the blood. 6. The main buffering system in the blood consists of... ~~A.~~ H2CO3 and HCO3- B. HCO3- and CO32- C. H3PO4 and H2PO4- D. H2PO4- and HPO42- E. NH3 and NH4+ Reasons for choosing the answer above: H2CO3- → conjugate base HCO3- → bicarbonate ion
A. Sistem penyangga dalam darah adalah pasangan asam karbonat (H_2CO_3) dan bikarbonat (HCO_3^-)	A. The buffering system in the blood consists of the carbonic acid (H_2CO_3) and bicarbonate (HCO_3^-) pair.

Figure 7. Students' answers to question number 6


Bacaan untuk soal no. 25 sampai 27
Rika dan teman-temannya membuat larutan penyangga yang berasal dari asam lemah dan basa konjugasinya. Rika mencampurkan 50 mL larutan HCOOH 1 M dengan 50 mL larutan HCOONa 1 M. Sebelum mengecek pH larutan penyangga yang dibuatnya dengan pH meter, Rika dan teman-temannya diminta untuk melakukan perhitungan pH teoretis menggunakan rumus. (Ka HCOOH = $1,8 \times 10^{-4}$.)
25. Berapa pH larutan penyangga yang dibuat Rika dan teman-temannya?
A. 1,8 – log 4
B. 3,6 – log 4
C. 4 – log 3,6
D. 4 – log 1,8
E. 10 + log 1,8

Alasan memilih jawaban di atas:

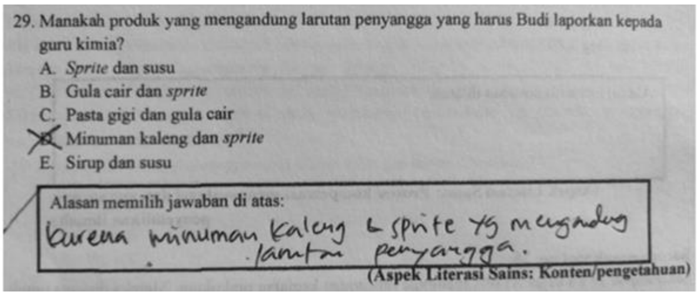
(Aspek Literasi Sains: Proses/ kompetensi mengevaluasi dan merancang penyelidikan ilmiah)

$H^+ = \sqrt{\frac{10^{-14} \cdot 10}{1,8 \times 10^{-4}} \cdot 5 \times 10^{-2}}$
$= 1,8 \times 10^{-4}$
pH = 4 – log 1,8

Jumlah mol HCOOH = 50 mL x 1 M = 50 mmol
Jumlah mol HCOONa = 50 mL x 1 M = 50 mmol

$$[H+] = Ka \cdot \frac{\text{mol HCOOH}}{\text{mol HCOONa}}$$
$$= 1,8 \times 10\text{-}4 \;.\; 50\ mmol 50\ mmol$$
$$= 1,8 \times 10\text{-}4$$
$$pH \;= 4 - \log 1,8$$

Figure 9. Students' Answers and Answer Keys on question number 25


29. Manakah produk yang mengandung larutan penyangga yang harus Budi laporkan kepada guru kimia?
A. *Sprite* dan susu
B. Gula cair dan *sprite*
C. Pasta gigi dan gula cair
D. Minuman kaleng dan *sprite*
E. Sirup dan susu

Alasan memilih jawaban di atas:
karena minuman kaleng & sprite yg mengandung larutan penyangga.

(Aspek Literasi Sains: Konten/pengetahuan)

D	Larutan penyangga banyak digunakan pada beberapa produk kebutuhan sehari-hari, antara lain sirup, pasta gigi, minuman kaleng, dan minuman bersoda

Figure 8. Answers and answer keys for question number 29

Conclusion

This study shows that the level of students' scientific literacy in the cognitive aspect is still very low, with an average achievement of 33.167%, falling into the "very inadequate" category. The distribution of scientific literacy levels shows that 34.3% of students are at the basic literacy level (illiteracy), 65.1% at nominal literacy, 0.23% at functional literacy, and only 0.33% have achieved conceptual literacy. This finding indicates that most students still experience misconceptions and difficulties in linking science concepts with their application in everyday life. For this reason, further research needs to be directed at developing teaching materials and learning strategies that are more contextual, which connect science material with real situations and are relevant to students. This approach is expected to make learning more meaningful, improve understanding, and help students realize the usefulness of the knowledge learned. When material is presented through a familiar context, students tend to understand more easily and be more motivated in the learning process.

References

Agustina, N. Q., Pratama, O. Y., Zahidah, N., Yuari, C. V., & Reyfaldy, M. I. (2024). Understanding students' perceptions of the challenges of teaching in the fourth industrial revolution in a private university in Yogyakarta. *SHS Web of Conferences*, *202*, 06014. https://doi.org/10.1051/shsconf/202420206014

Anshar, M. A., Rahayu, Y. S., Erman, E., Karimah, K., & Rofiq, A. (2023). Analysis of Umar Masud Junior High School Students' Science Literacy Ability. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, *9*(2), 926–930. https://doi.org/10.29303/jppipa.v9i2.2667

Aquino, J., Caingcoy, W., Zamora, R., & Diquito, T. J. (2025a). Scientific Literacy Assessment Using Bybee's Scientific Model: Towards a More Sustainable Science Education. *Journal of Arts, Humanities and Social Science*, *2*(1), 8–21. https://doi.org/10.69739/jahss.v2i1.207

Bramastia, B., & Rahayu, S. (2023). Study of Science Learning Based on Scientific Literacy in Improving Critical Thinking: A Scoping Review. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 499–510. https://doi.org/10.29303/jppipa.v9i8.5667

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883. https://doi.org/10.1002/tea.20333

Bybee, R. W. (1997). *Achieving Scientific Literacy: From Purposes to Practices*. https://api.semanticscholar.org/CorpusID:151275152

Cerna, S. C., Fuster-Guillén, D., Castro, A. S., Leyva, H. W. M., & Ramírez, T. V. C. (2021). Scientific literacy: a key part of school contexts. *Revista Tempos e Espaços Em Educação*, *14*(33), e15611. https://doi.org/10.20952/revtee.v14i33.15611

Costa, A., Loureiro, M., & Ferreira, M. E. (2021). Scientific Literacy: The Conceptual Framework Prevailing over the First Decade of the Twenty-First Century. *Revista Colombiana de Educación*, *1*(81). https://doi.org/10.17227/rce.num81-10293

Dawson, C., Julku, H., Pihlajamäki, M., Kaakinen, J. K., Schooler, J. W., & Simola, J. (2024). Evidence-based scientific thinking and decision-making in everyday life. *Cognitive Research: Principles and Implications*, *9*(1), 50. https://doi.org/10.1186/s41235-024-00578-2

Dewi, C. A., Khery, Y., & Erna, M. (2019). An Ethnoscience Study in Chemistry Learning to Develop Scientific Literacy. *Jurnal Pendidikan IPA Indonesia*, *8*(2), 279–287. https://doi.org/10.15294/JPII.V8I2.19261

Gormally, C., Brickman, P., & Lutz, M. (2012). Developing a Test of Scientific Literacy Skills (TOSLS): Measuring Undergraduates' Evaluation of Scientific Information and Arguments. *CBE—Life Sciences Education*, *11*(4), 364–377. https://doi.org/10.1187/cbe.12-03-0026

Habiddin, H., Ulfa, R., & Utomo, Y. (2024). Interactive instructional teaching method (IITM); contribution towards students' ability in answering unfamiliar types questions of buffer solution. *Chemistry Teacher International*, *6*(1), 49–58. https://doi.org/10.1515/cti-2022-0024

Hamidah, I., Luzyawati, L., & Ratnasari, A. (2025). *Teacher and student perception of integrated science literacy in information, technology, and environment*. https://doi.org/10.31943/mangiferaedu

Haryani, S., Sakti, A. T., Dewi, S. H., & Prasetya, A. T. (2023). *Development of content knowledge instruments in the form of two tiers based on scientific literacy on buffer solutions*. 030032. https://doi.org/10.1063/5.0140542

Howell, E. L., & Brossard, D. (2021). (Mis)informed about what? What it means to be a science-literate citizen in a digital world. *Proceedings of the National Academy of Sciences*, *118*(15). https://doi.org/10.1073/pnas.1912436117

Implementation of Virtual Laboratory Platform to Study Human Buffer Solutions in the Era of COVID-19. (2020). *Educational Research Applications*. https://doi.org/10.29011/2575-7032.100177

Irwanto, I., Pratiwi, Y., & Manurung, S. F. (2024). Enhancing Students' Conceptual Understanding of Buffer Solutions Through Peer-Led Problem-Based Learning. *International Journal of Religion*, *5*(6), 369–378. https://doi.org/10.61707/0vm86663

Khoiriza, I., Aminatun, T., Pramusinta, W., & Hujatulatif, A. (2021). *Science Learning and Environment: Analysis of Student's Scientific Literacy Based on Indonesia's Waste Problem*. https://doi.org/10.2991/assehr.k.210326.111

Kumalasari, M., & Suyono, S. (2023). Validity of Student Worksheet Based on Scientific Literacy to Train Argumentation Skills on Buffer Solution. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(4), 579. https://doi.org/10.33394/hjkk.v11i4.8635

Lestari, A., & Atun, S. (2021). The Effectiveness of E-Module on Buffer Solutions to Improve Students' Higher-Order Thinking Skills and Self-Regulated Learning. *JTK (Jurnal Tadris Kimiya)*, *6*(2), 254–266. https://doi.org/10.15575/jtk.v6i2.13772

Li, Y., & Guo, M. (2021). Scientific Literacy in Communicating Science and Socio-Scientific Issues: Prospects and Challenges. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.758000

Lopes, R. M., Comarú, M. W., Pierini, M. F., de Souza, R. A., & Hauser-Davis, R. A. (2024). Scientific communication and scientific literacy for the public perception of the importance of environmental quality for public health. *Frontiers in Communication*, *9*. https://doi.org/10.3389/fcomm.2024.1297246

Mujakir, M., Nurmalahayati, N., Safrijal, S., Salsabil, P., Fatma, E., & Zainuddin, Z. (2024). Efforts to Improve Scientific Literacy Capabilities in Indonesia: Systematic Literature Review. *Online Learning In Educational Research (OLER)*, *4*(1), 49–59. https://doi.org/10.58524/oler.v4i1.395

Muntholib, M., Yusnaini, M. L., Khusmawardani, E., Sa'dila, R., Joharmawan, R., & Yahmin, Y. (2023). *Analysis of eleventh graders' scientific literacy on buffer*. 030012. https://doi.org/10.1063/5.0112766

OECD. (2019). PISA 2018 Results (Volume I): What Students Know and Can Do. Paris: OECD Publishing.

Pasternak Taschner, N., & Almeida, P. (2024). Teaching scientific evidence and critical thinking for policy making. *Biology Methods and Protocols*, *9*(1). https://doi.org/10.1093/biomethods/bpae023

Permatasari, P., & Fitriza, Z. (2019). Analisis Literasi Sains Siswa Madrasah Aliyah pada Aspek Konten, Konteks, dan Kompetensi Materi Larutan Penyangga. *EduKimia*, *1*(1). https://doi.org/10.24036/ekj.v1i1.104087

Prasetya, C., & Maisarah. (2024). The Effect of Chemistry Teaching Materials on Scientific Literacy and Critical Reasoning in SMA Negeri Langsa. *IJCER (International Journal of Chemistry Education Research)*, 1–6. https://doi.org/10.20885/ijcer.vol8.iss1.art1

Rahmawati, Y., Erdawati, E., Ridwan, A., Veronica, N., & Hadiana, D. (2024). Developing students' chemical literacy through the integration of dilemma stories into a STEAM project on petroleum topic. *Journal of Technology and Science Education*, *14*(2), 376. https://doi.org/10.3926/jotse.2221

Salame, I. I., Ramirez, L., Nikolic, D., & Krauss, D. (2022). Investigating Students' Difficulties and Approaches to Solving Buffer Related Problems. *International Journal of Instruction*, *15*(1), 911–926. https://doi.org/10.29333/iji.2022.15152a

Salirawati, D. (2013). Pengembangan instrumen pendeteksi miskonsepsi kesetimbangan kimia pada peserta didik SMA. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *15*(2), 232–249. https://doi.org/10.21831/pep.v15i2.1095

Sehasari Dewi, N., & Mulyani, S. (2024). Enhancing conceptual unerstanding of Buffer Sollution with an intertextual E-Book Prototype. *Jurnal Kimia Dan Pendidikan Kimia (JKPK)*, *9*(2), 311–323. https://doi.org/10.20961/jkpk.v9i1.85269

Shahzadi, I., & Nasreen, A. (2020). *Assessing Scientific Literacy Levels among Secondary School Science Students of District Lahore* (Vol. 42, Issue 3).

Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chem. Educ. Res. Pract.*, *7*(4), 203–225. https://doi.org/10.1039/B6RP90011A

Soobard, R., & Rannikmäe, M. (2011). Assessing student's level of scientific literacy using interdisciplinary scenarios. In *Science Education International* (Vol. 22, Issue 2).

Sumarni, W., Prasida, H. W., & Sumarti, S. S. (2017). Pengembangan Instrumen Penilaian Kemampuan Kognitif dan Afektif Berbasis Literasi Sains pada Materi Larutan Penyangga. *Pembelajaran Aktif Dan Profesionalisme Guru Di Era Global. In Prosiding of Seminar Nasional Alfa VII*, 457–467.

Tuttle, M. J., Cejas, D., Kang, D., Muchaamba, F., Goncarovs, B., Ozakman, Y., Aziz, F., & Orelle, A. (2023). Promoting Science Literacy and Awareness across the Globe: the Role of Scientists as Science Ambassadors. *Journal of Microbiology & Biology Education*, *24*(2). https://doi.org/10.1128/jmbe.00041-23

Wahab, M. N. N. D., Wasis, Prahani, B. K., Haryono, H. E., & Jatmiko, B. (2025). Research Trends of Student Scientific Literacy Assessment to Support Quality Education. *Journal of Lifestyle and SDGs Review*, *5*(1), e03916. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n01.pe03916

Wahyuni, T. S., & Silfianah, I. (2024). Transforming science literacy: assessing the ability of chemistry teacher candidates through the viewpoint of Islamic values. *Psychology, Evaluation, and Technology in Educational Research*, *7*(1). https://doi.org/10.33292/petier.v7i1.233

Wiyarsi, A., Prodjosantoso, A. K., & Nugraheni, A. R. E. (2021). Promoting Students' Scientific Habits of Mind and Chemical Literacy Using the Context of Socio-Scientific Issues on the Inquiry Learning. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.660495

Wulandari, N., & Wulandari, N. (2016). Analisis kemampuan literasi sains pada aspek pengetahuan dan kompetensi sains siswa SMP pada materi kalor. *EDUSAINS*, *8*(1). https://doi.org/10.15408/es.v8i1.1762

Yudha, S., Simorangkir, M., & Nurfajriani, N. (2023). Analysis of Science Literacy of XI Class Students In Buffer Solution Materials. *Journal of Learning Improvement and Lesson Study*, *3*(2), 1–6. https://doi.org/10.24036/jlils.v3i2.46

Yusmaita, E., & Nasra, E. (2017). Perancangan assesmen literasi kimia dengan menggunakan model of educational rekonstruksion (MER) pada tema: "air sebagai pelarut universal". *JURNAL EKSAKTA PENDIDIKAN (JEP)*, *1*(2), 49. https://doi.org/10.24036/jep.v1i2.66

Zua, B. (2021). Literacy: Gateway to a World of Exploits. *International Journal of Education and Literacy Studies*, *9*(1), 96. https://doi.org/10.7575/aiac.ijels.v.9n.1p.96