Chemical Literacy Test Instrument Designing on Buffer Topic using Model of Educational Reconstruction (MER)

E Yusmaita\(^1\), L G Anthonio\(^1\) and I Rivaldo\(^2\)

\(^1\)Chemistry Department, Faculty of Mathematics and Sciences, Universitas Negeri Padang, Indonesia
\(^2\)Graduate School, Master of Education in Chemistry, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

*ekayusmaita@fmipa.unp.ac.id

Abstract. Chemical literacy test serves as measurement instrument capable of measuring student’s understanding of chemical concepts, attitude, and the application of chemistry in life. The measurement of chemical literacy skill requires good test instrument with valid and reliable criteria. Chemical literacy test instrument designing on buffer is done to help students understand chemical literacy-based questions, they are able to understand chemical science, communicate in verbal and writing, and also apply their abilities to solve problems in daily life. The research aims to create the test instrument that could be used to measure the chemical literacy on the topic of buffer and determine the validity of the instrument. The instrument was validated by three lecturers and validation data analysed using the Aikens’V method. Validation result shows that the instrument have valid category. The result indicated that the chemical literacy test instrument that has been created can be used to measure the chemical literacy of students.

1. Introduction

It is important to develop scientific literacy because understanding science offers personal satisfaction and pleasure that comes after understanding and studying nature; every individual needs information and scientific thinking skills to solve problems related to science and technology; and scientific literacy is important in the world of work because more jobs require high-level skills where a person must have the ability to reason, think creatively, make decisions and solve problems related to science[1]. The main goal of developing scientific literacy is that students can understand problems and be able to make decisions when there are problems related to science and technology[2].

Chemical literacy is part of scientific literacy. Chemical literacy according to Shwartz, Ben-Zvi, & Hofstein, consists of several components including understanding chemical properties, norms, methods, understanding chemical theories, concepts, and models, understanding how chemistry-based science and technology are interrelated each other because science seeks to produce explanations of nature whereas chemical technology seeks to change the world itself[3], understand the nature of the prevailing chemical phenomena to produce changes or variations in the phenomenon/situation for the better, respect the impact of chemistry, and chemical technology related to society[4]. Students who have chemical literacy are expected to be able to apply chemical concepts to explain the phenomena that occur around them scientifically and apply these phenomena to facilitate the activities they carry out. Students who have chemical literacy wisely can balance the development of science and its impact on
the environment so that damage and pollution do not occur due to improper use of chemical substances or industrial waste. A caring and environmental awareness attitude is reflected in the personality of students who have chemical literacy[5].

Students must have chemical literacy skills in chemistry learning. Assessment of chemical literacy skills is needed to support more meaningful learning and it is important to determine the level of achievement of students' understanding of learning[6]. An assessment instrument that can assess chemical literacy skills needs to be developed because to measure achievement in chemistry learning requires an assessment that not only assesses the level of understanding and memorization of students, but is also able to assess the application of students' concepts when facing an issue[7].

The design of questions based on chemical literacy is one way to help students understand chemical science, communicate it orally and in writing, and be able to apply their abilities to solve problems in everyday life that are adapted to the social context and the context of society[8]. Chemical literacy assessment instruments are an important factor that must be prepared to help teachers assess and evaluate learning. Explains that teachers should spend about a third to a quarter of the total time to make assessments in the learning process[9]. Therefore, it needs special attention and careful planning in planning and assessing the learning process. Starting the right and suitable instruments according to the needs and goals to be achieved. The chemical literacy assessment based on the aspects of content, context, high-level learning skills, and attitudes which refer to the chemical literacy domain created by Shwartz as well as answer assessments based on the level of scientific literacy levels.

2. Method

Type of research is a development using the Model of Educational Reconstruction (MER). The stages of designing questions using MER used three stages (1) content structure analysis (2) empirical investigation (3) learning construction[10]. One of the fundamental ideas of this model is a content structure for teaching can not be taken directly from the structure of science content, but must be reconstructed by students learning objectives cognitive and affective[11]. The analysis of content structure stage consists of three steps, namely syllabus analysis, content structure analysis, and context analysis. In the second stage, empirical studies carried out validation activities in the field through judgment experts. The validation data obtained were analyzed using the Aikens'V scale.

\[
V = \frac{\sum s}{n(c - 1)}
\]  

Description:

\(v\) = Aiken’s V scale  
\(s\) = \(r - l\)  
\(n\) = number of panels of validator  
\(r\) = the numbers given by a validator  
\(l\) = lowest validity assessment (1)  
\(c\) = highest validity assessment (5)

Stage 1. Analysis of Content Structure

Science content structure for instruction is developed on the grounds of science content structure and educational issues (aims of instruction’s perspectives), this stage consist of:

a. Syllabus Analysis

Syllabus analysis is the first stage to be carried out, here using basic competencies for senior high school 3.12. Explain the working principle, pH calculation, and the role of buffer solutions in living things. The selected basic competencies are derived to a Competency Achievement Indicator (GPA).

b. Content analysis

Content analysis is the clarification of the subject matter in a buffer solution as well as the process of viewing a material using several sources, namely university chemistry books, and journals. This is done to check the correctness of the concepts in the buffer solution material[12].
c. Context analysis
Context analysis is how to connect the content contained in the buffer solution material with the application of the buffer solution concept in life so that it is easier to understand how the concept of the buffer solution itself. Context analysis can be referenced from journals, articles, or several other sources according to the theme.

Making chemical literacy questions is the next step that must be done. The components contained in the lattice for chemical litigation. The sections on the basic competencies, GPA, cognitive level, knowledge level that refers to bloom taxonomy, aspects of chemical literacy (content, context, HOLS, and attitudes), and question cards. The drafting of the test instrument is completed with question cards along with scoring guidelines for chemical literacy questions. The designed question card consists of several components, namely basic competencies, indicators of competency achievement, material, question indicators, cognitive levels, knowledge levels, scoring rubrics or scoring guidelines, and chemical literacy levels. The answers to chemical literacy questions based on the level of chemical literacy are expected to be in the form of scientific illiteracy (score 0), functional scientific literacy (score 1), nominal scientific literacy (score 2), conceptual scientific literacy (score 3), multidimensional scientific literacy (score 4).

3. Results and Discussion

3.1. Empirical Investigation
The results of the validation carried out by three validators as Subject Matter Expert (SME) were the content validation value (v) using the Aikens’V formula. Based on the results of the content validation analysis, it was found that all item items were included in the “valid” category, the total score was 1.03. The following is the content validation value according to Table 1.

| Item number | Judgment Expert | \( \sum s \) | \([n (c-1)]\) | V | Category |
|-------------|-----------------|------------|-------------|---|---------|
| 1.          | 4 4 4           | 12         | 12          | 1 | Valid   |
| 2.          | 4 4 4           | 12         | 12          | 1 | Valid   |
| 3.          | 4 4 4           | 12         | 12          | 1 | Valid   |
| 4.          | 4 4 4.3         | 12,3       | 12          | 1,02 | Valid |
| 5.          | 4 4 4.3         | 12,3       | 12          | 1,02 | Valid |
| 6.          | 4 4 4           | 12         | 12          | 1 | Valid   |
| 7.          | 4 4,3 5         | 13,5       | 12          | 1,10 | Valid |
| 8.          | 4 4 5           | 13         | 12          | 1,08 | Valid   |
| 9.          | 4 4 5           | 13         | 12          | 1,08 | Valid   |
| 10.         | 4 4 5           | 13         | 12          | 1,08 | Valid   |
| **Mean**    | **4 4,03 4,64** | **12,51**  | **12**      | **1,03** | **Valid** |

In the content structure analysis, there is syllabus analysis, content analysis, context analysis, question grids, and a draft test instrument is obtained. The empirical investigation was carried out on SME as many as three validators.

The design of the instrument for chemical literacy consists of a question discourse, a question, and an assessment rubric. The answers to the chemical literacy questions designed are assessed based on the level of chemical literacy, which is as follows.

1. Scientific illiteracy: where students cannot answer the questions or the answers was wrong
2. Nominal scientific literacy: where students can answer briefly and correctly, but there are misconceptions in answers
3. Functional scientific literacy: where students can answer correctly but have a limited understanding of the concept
4. Conceptual scientific literacy: where students' answers are correct and can relate some of the concepts they have learned
5. Multidimensional scientific literacy: students can answer questions correctly and more broadly, and can develop some understanding based on developments in science and technology.

Chemical literacy questions are designed to contain several components: chemical literacy, including content aspects: which are chemical concepts contained in the questions, context aspects: which are the application or contextual of concepts in everyday life, aspects of High Order Learning Skills (HOLS), is the ability to identify questions, seek information and analyze problems that occur, and aspects of attitude[13].

The design of chemical literacy questions consisted of ten questions with seven discourses were for question number one regarding blood consisted of three questions and questions for number two consisted of two item questions. One of them is as described in table 2 and 3.

**Chemistry Unit 1. Enamel**

![Figure 1. Drawing of tooth enamel](image)

The amount of food we consume every day can affect oral health. If you consume foods that are too acidic or foods that contain alkaline it will damage the enamel or tooth enamel. Luckily in the mouth, there is saliva that contains phosphate compounds (H2PO4⁻ / HPO4²⁻) so that the pH in the mouth remains stable in the pH range of 6.8.

**Table 2. Examples of Design Chemical Literacy Problems**

| Questions                                                                 | Answer                                                                 | Scoring               |
|---------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------|
| 1.1 Explain the acid and base pairs of the components of the buffer solution contained in the phosphate-containing saliva! | In the mouth, there is saliva that contains phosphate, the function of the phosphate buffer to maintain the pH in the mouth so it doesn't damage tooth enamel. The acid or base pair reacts with the conjugate acid or base. Acid + base conjugate of phosphate in saliva H⁺ + HPO₄²⁻ → H₂PO₄⁻ Base pair + phosphate buffer conjugate acid H₂PO₄⁻ + OH⁻ → HPO₄²⁻ + H₂O | score : 3 (Conceptual Scientific Literacy) |
| 1.2 How is your attitude to be able to maintain tooth enamel to stay healthy? | By brushing your teeth at least twice. | Score : 2 (Functional Scientific Literacy) |
In the questions unit 1, the content aspect in the question above is in the phosphate buffer solution found in saliva, while the context aspect is in tooth enamel, as for the attitude aspect in the question where students are asked to convey what they do to keep tooth enamel healthy. As for the literacy level, question number 1.1 arrives at conceptual scientific literacy, this is because the question demands ask students to explain, while question number 1.2 the answer to the literacy level only reaches functional scientific literacy, this is because the demands of the questions ask for students' opinions. The validation value for this question is 1 with the valid category.

An example of a chemical literacy problem with a discourse on blood. The design of questions and aspects of chemical literacy can be seen in Table 3.

Table 3. Example of problem design

| Chemistry Unit 2 : Blood |
|--------------------------|
| **Figure 2. Blood** |

When we eat foods that contain lots of acids such as oranges, chemically many H+ ions enter the body. The entry of H+ ions causes the pH of our blood to drop. Luckily we have a buffer solution in the blood that is able to bind H+ ions so that our blood pH stabilizes. Likewise, if we eat foods that are alkaline, this will increase the pH of the blood. The entry of OH- ions from alkaline food or drinks will also react with buffer solutions in the blood. Normal blood pH is in the range of 7.35 - 7.45. the buffer solution present in the blood is a carbonate buffer H2CO3/HCO3-

**Questions**

2.1 What are the properties of carbonate buffer solutions to keep blood pH stable?

2.2 What is the reaction that occurs in the carbonate buffer with acids and bases? Please explain.

2.3 What do you think if there are no buffer compounds in our bodies, what will happen?

| **Answer** | **Scoring** |
|------------|-------------|
| 2.1 The carbonate buffer in the blood works by binding to H+ ions or OH- ions which come from the food or drink we consume, where the ions (H +) contained in acids are bound by bases (HCO3-) and likewise for ions (OH-) contained in the base is bound by an acid (H2CO3). This occurs to produce its conjugate acid-base pairs. So that blood pH remains stable. | Score : 3 (Conceptual Scientific Literacy) |
| 2.2 The ion (H +) derived from the acid that is consumed will react with the alkaline compound to produce a conjugate base compound H+ + HCO3- → H2CO3. The ion (OH-) derived from the consumed base will react with the acidic compound to produce a conjugation pair and a buffer solution is formed. OH- + H2CO3 → HCO3- + H2O | Score : 2 (Functional Scientific Literacy) |
| 2.3 What will happen if there is no buffer in the blood is that the body will be susceptible to disease because there is no pH stability in the blood, when consuming acid, or when consuming alkaline, this will later endanger the body. | Score : 2 (Functional Scientific Literacy) |
In the questions unit 2, there are aspects of content, aspects of context, and aspects of attitude. The content aspect in the question above is found in the carbonate buffer solution found in human blood cells, while the context aspect is blood, as for the attitude aspect in the problem where students imagine that there is no buffer solution in the human body. As for the literacy level, question number a arrives at conceptual scientific literacy because the question demands ask students to explain, while question number b the answer to the literacy level only comes to functional scientific literacy and so does question number c to functional scientific literacy. this is because the demands of the question ask the opinions of students. The validation value for this question is 1 with the valid category.

The results of the content validation analysis of ten questions with seven discourses in various contexts obtained an overall V value of 1.03. This indicates that all the items designed are in the "valid" category, so it can be said that the chemical literacy assessment instrument designed has been tested on students.

4. Conclusion

Based on the research that has been done, a test instrument for chemical literacy using the Model of Educational Reconstruction (MER) on the buffer solution material for class XI SMA / MA consists of ten items with content validation values by Judgment experts using the Aikens'V scale of 1.03 with the category "valid."

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