Analysis of student concept understanding on the material of buffer solution using three-tier test assisted by multiple representation teaching materials

A Drastisianti1,2,*, E Susilaningsih3, N Wijayati, E I Nada1,2, N Alawiyah1,2 and Supartono3

1 Department of Chemistry Education, Faculty of Sciences and Technology, Universitas Islam Negeri Walisongo Semarang, Indonesia
2 Natural Science Study Program, Graduate Program, Universitas Negeri Semarang, Indonesia
3 Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia

*Corresponding author: apriliana.drastisianti@walisongo.ac.id; apriliana.adda@gmail.com

Abstract. This research is a mix method research with the design of sequential explanatory strategy. This research aims to know and describe students' conceptual understanding of buffer solution material and to get student response to teaching material of multiple representation buffers (macroscopic, submicroscopic, and symbolic). Research subjects were 114 students from eleven grade of natural science class (XI MIPA 3, XI MIPA 4, and XI MIPA 5), state senior high school 12 (SMA Negeri 12) Semarang, Indonesia, academic year 2017/2018. Quantitative data was collected through a diagnostic test in the form of three-tier multiple choice test totaling 20 items and questionnaires to find out the student's response to multiple representation of teaching materials. Qualitative data is obtained by interview to confirm student answers. Multiple representation materials validated by three validators and received very excellent results with an average score of 190.33 from 212. The average score of the questionnaire was 30.026 with a proper category, and Alpha Cronbach reliability was 0.884. The results of this study indicate that the understanding of the concept of students on the material of buffer solution as much as 47.061% understand, 29.868% less understood, 12.763% misconception, and 10.307% do not understand.

1. Introduction

Understanding concepts are essential for students. Understanding concepts based only on fundamental knowledge alone will lead to an understanding that can be true or false. Mastery of early knowledge owned by learners is very influential on the acquisition of subsequent knowledge. New concepts must be integrated into the knowledge system before use as a secure foundation for developing the next concepts [1]. Students may experience misconceptions when trying to shape knowledge by translating new experiences in the form of early conceptions [2]. The new experience formed can come from learning in the classroom and the student's environment.
Abstract chemical objects can cause students to experience difficulties, thus making their interpretations of the concepts studied [3]. The teaching material of the buffer solution is one of the abstract material. Difficulties experienced by students can lead to non-achievement of learning outcomes optimally. Abstract concepts need to be explained in various forms of representation that can visualize the entire material of the buffer solution so that it can be learned easily.

Multi-representation is needed by students to understand and develop the concept [4,5] states that learning chemistry involves three levels: macroscopic, submicroscopic, and symbolic. Students can achieve a conceptual understanding if they can relate the observed macroscopic changes to the rearrangement of particles occurring at the submicroscopic level and to the precise chemical equations at the symbolic level [6].

Learning resources are one means to stimulate student learning activities. Based on preliminary observations made, chemistry learning in eleven grade of natural science class (XI MIPA 3, XI MIPA 4, and XI MIPA 5), state senior high school 12 (SMA Negeri 12) Semarang, Indonesia, using the book package and student worksheet. This study uses multiple representation materials containing buffer material covering macroscopic, submicroscopic, and symbolic aspects. Learning using multiple representation materials ends with a test.

The test form is a three-tier test consisting of multiple choice with an open reason to see the argument contained in the student's answer [11]. Teachers can analyze students' understanding objectively because, in addition to answering multiple choice questions and a level of belief in answers, the student's reason for multiple choice answers can be revealed so that conceptual understanding can be easily and precisely identified.

This study aims to find out the students' conceptual understanding on buffer material using the diagnostic test in the form of three-tier test with learning using multiple representation teaching materials which contains macroscopic, submicroscopic, and symbolic aspects.

2. Methods

This study was conducted in the even semester of the academic year 2017/2018. Research subjects were 114 students from eleven grade of natural science class (XI MIPA 3, XI MIPA 4, and XI MIPA 5), state senior high school 12 (SMA Negeri 12) Semarang, Indonesia.

The method used is a mixed method with sequential explanatory strategy design because the analysis of the concept of buffer material concept requires quantitative and qualitative data [7,9,10]. Data collection and quantitative data analysis in the first stage and followed by collecting and analyzing qualitative data in the second stage to strengthen the results of quantitative research conducted in the first stage.

Quantitative data obtained from the written test in the form of three-tier multiple choice test and questionnaire. The written test consists of 20 items with the first level in the form of questions about the second level, the choice of answers with five choices, and level three is the reason for the answer with an open reason. Students' answers were analyzed to distinguish between students who understood concepts, lack of concept, misconception, and ignorance of concepts [9,10]. Categories of conceptual understanding shown in Table 1. Analysis of student answers was done by calculating the percentage with the formula:

\[ P = \frac{f}{N} \times 100\% \]  

Note:
- \( P \) = category percentage
- \( F \) = number of students per category
- \( N \) = number of all students who are the subject of the study
The validity of the test instrument was done by expert judgment and reliability method with KR-21 formula. Questionnaire to find out the student's response to multiple representation teaching materials. The questionnaire validity was done by expert judgment method and reliability with Alpha Cronbach formula. Qualitative data were obtained after the student performs a written test by interviewing to confirm student answers on the written test. The validity of the instrument of the interview guideline was done by expert judgment method.

| Answer | Reason | Certainty | Description          |
|--------|--------|-----------|----------------------|
| True   | True   | Sure      | The Understanding concept |
| True   | True   | Not sure  | Less understanding   |
| True   | False  | Sure      | Misconception        |
| True   | False  | Not sure  | Less understanding   |
| False  | True   | Not sure  | Misconception        |
| False  | True   | Not sure  | Less understanding   |
| False  | False  | Sure      | Misconception        |
| False  | False  | Not sure  | Do not understand    |

3. Results and Discussion

The first step in this research is the preparation of multiple representation materials (macroscopic, submicroscopic, and symbolic aspects) of buffer solution material. The teaching materials before being used are validated by three validators and have been revised based on validator suggestions. Validation of the feasibility of teaching materials includes content feasibility aspects, the feasibility of presentation, language, and graph with a total of 53 points statement. The average score of the three validators is 190.333 of the total score of 212 with a very decent category. Student response to teaching materials was made by filling in the questionnaire. The questionnaires were filled by students of class XI MIPA 3 totaling 38 students. The average score of the questionnaire result is 30,026 with a proper category, and the reliability result of Alpha Cronbach is 0.884, which means reliable questionnaire for use. Student responses to instructional materials shown in Figure. 1.
The concept of buffer material comprises means of buffer solution, the buffer solution component, buffer solution mode, buffer pH, and buffer solution function. The result of the analysis shows the students' concept of understanding on each item. The percentage of concept level understanding of 114 students on buffer solution material shown in Table 2.

Based on Table 2, items 8 and 10 have a high understanding of the concept of 72.807% and 71.930%. Item 8 is adapted from practical questions that have been done during the learning process. Practicum can strengthen students' long-term memory regarding macroscopic aspects [9-12]. The indicator about eight that is student able to determine test to a buffer solution and macroscopic aspect indicator. The macroscopic aspect can be seen clearly by the students in the form of a universal color change indicator used to test a buffer solution. Students can see the color change of the universal indicator paper when the solution is added a slightly stronger acid, slightly stronger base, and diluted and determines the pH of the solution to conclude further whether the solution is a buffer solution or not. The indicator of item 10 identifies the equation of the buffer formation reaction of the buffer solution component and the symbolic aspect indicator. Students can write the equation of reaction between a weak acid (citric acid) with a strong base (NaOH), which will produce sodium citrate to form acid buffer solution.

Table 2. Percentage level of understanding of student concept on buffer material

| Item | Understanding Concept | Less Understanding | Misconception | Do Not Understand | The number of students who understand |
|------|-----------------------|-------------------|---------------|------------------|-------------------------------------|
| 1    | 58.772                | 9.649            | 18.421        | 13.158           | 67                                  |
| 2    | 32.456                | 21.930           | 34.211        | 11.404           | 37                                  |
| 3    | 64.035                | 18.421           | 15.789        | 1.754            | 73                                  |
| 4    | 51.754                | 20.175           | 16.667        | 11.404           | 59                                  |
| 5    | 38.596                | 35.965           | 9.649         | 15.789           | 44                                  |
| 6    | 36.842                | 21.930           | 18.421        | 22.807           | 42                                  |
| 7    | 42.982                | 22.807           | 21.930        | 12.281           | 49                                  |
| 8    | 72.807                | 16.667           | 6.140         | 4.386            | 83                                  |
| 9    | 61.404                | 26.316           | 4.386         | 7.895            | 70                                  |
| 10   | 71.930                | 23.684           | 0.877         | 3.509            | 82                                  |
| 11   | 39.474                | 40.351           | 11.404        | 8.772            | 45                                  |
| 12   | 40.351                | 37.719           | 11.404        | 10.526           | 46                                  |
| 13   | 64.912                | 18.421           | 13.158        | 3.509            | 74                                  |
| 14   | 47.368                | 30.702           | 15.789        | 6.140            | 54                                  |
| 15   | 52.632                | 25.439           | 12.281        | 9.649            | 60                                  |
| 16   | 36.842                | 42.982           | 7.018         | 13.158           | 42                                  |
| 17   | 27.193                | 53.509           | 7.018         | 12.281           | 31                                  |
| 18   | 35.088                | 49.123           | 4.386         | 11.404           | 40                                  |
| 19   | 42.982                | 35.088           | 14.912        | 7.018            | 49                                  |
| 20   | 22.807                | 46.491           | 11.404        | 19.298           | 26                                  |
| Average | 47.061            | 29.868           | 12.763        | 10.307           | 53                                  |

Item 3, 9, and 13 respectively have a conceptual understanding level of 64.035%, 61.404%, and 64.912%. Item 3 with an indicator of students' ability to predict the effect of dilution on the pH of the
buffer and macroscopic aspect indicator. The macroscopic aspect in this question is the same as item 8 that students can see changes in the pH of the solution when diluted to test the nature of the buffer solution. Item 9, with a student indicator, can determine the pH of the buffer solution and the symbolic aspect indicator. The results of the interviews show that students consider that sodium benzoate is a strong base, so there are still many students who are in the less understood category because although the answers and the reasons are correct, it is not sure if the pH calculation is accurate. Item 13 with an indicator about the students can give examples of the application of buffer solution in everyday life and indicator submicroscopic aspect.

Items 1, 4, and 15 respectively have a level of understanding of the concept of 58.772%, 51.754%, and 52.632%. The indicator about item 1 is that students can classify the solution as a buffer or not and a submicroscopic indicator. A submicroscopic diagram represents a solution containing one or more \( H_2A, \text{NaHA}, \) and \( \text{Na}_2A \) where \( H_2A \) is a diprotic acid, as shown in Figure 2.

Students who understand the concept of writing the reason for the answer of solution 2 is not a buffer because it contains only weak acid \( H_2A \) alone, while the acid buffer solution contains a weak acid and its conjugate base. The indicator item 4 is determining the pH of the highest and lowest buffer solution and the submicroscopic aspect indicator. Students are required to determine the solution which has the highest and lowest pH based on the submicroscopic diagram listed in the problem. Students who understand the concept of writing the answer [\( \text{H}^+ \)] are low if the conjugate base mol is high. Solution 2 has a conjugate base mol (\( A^- \)) higher than the weak acid mol, so [\( \text{H}^+ \)] is low, and the pH is high. The indicator item 15 specifies the buffer solution was having the smallest buffer capacity and the submicroscopic aspect indicator. The concept comprehension test results show that more than half the students understood the concept by writing the answer the more mole the buffer component, the higher the ability to maintain the pH (the higher the buffer capacity), although the component mole ratio is the same. Based on the results of the answers are still many students who wrote the answer correctly, but not sure. This result is reinforced by the student's answer on item 2 that has not been able to distinguish between conjugate acids and bases. Therefore, it indicates that the student has an incomplete understanding of the buffer capacity.

Item 7, 12, 14, and 19 respectively have a conceptual understanding level of 42.982%, 40.351%, 47.368%, and 42.982%. Item 7 is to interpret the acid-base titration curve to determine the area, which is the buffer zone and symbolic aspect indicator. Based on the interview results, the ability to read charts correctly is still low. The 12 item indicator is an example of a mixture of solutions, which is a buffer solution and a symbolic aspect indicator. Based on the results of answers and interviews, students in writing the reaction between acid and base is still not equalized. The item of 14 is a change that occurs when the weak acid \( \text{CH}_3\text{COOH} \) was added with the \( \text{NaCH}_3\text{COO} \) salt and macroscopic aspect indicator. Students write the answer that the weak acid when added with the salt it will form an acid buffer solution. The pH of the acid buffer solution will be higher than the weakly acidic pH due to the added base of the conjugate of the weak acid. This results showed the students have a conceptual understanding. Item 19 is to explain how the buffer solution and the submicroscopic indicator indicate. Students can define that the buffer solution has an acid and base component which, when it was acidified, an alkaline buffer component will defend it and vice versa.
Item 5, 6, 11, 16 and 18 respectively have concept comprehension rate of 38.596%, 36.842%, 39.474%, 36.842%, and 35.088%. Point 5 requires students to be able to determine the volume ratio to create buffer solutions with a predetermined pH of a weakly acidic solution and salt thereof. Understanding the concept of students on this problem is low because the interview results found that students consider NaCH$_3$COO as a strong base, not salt that contains a conjugate base of weak acid CH$_3$COOH. Point 6 requires students to be able to determine a solution mixture as a buffer solution or not and determine an image representing a balanced state of the mixture. Understanding students' concepts on these items are low because students find it difficult to represent the submicroscopic phenomena of a chemical reaction displayed through a diagram. Item 11 requires students to be able to calculate the pH of the alkaline buffer solution before and after the dilution. Based on the results of the answers and interviews, students hold that NH$_3$ as a base, so the pH calculation is incorrect. Results of answers and student interviews on item 16 also indicate that students have misconceptions concerning NH$_3$ as an acid because it does not contain OH$^-$ ions. Item 18 requires that the student be able to determine the pH of the buffer solution. Understanding students' concepts on these items are low because, from interviews, it was found that students have difficulty converting mass units to moles.

Item 17 and 20 levels of understanding of the concepts of 27.193% and 22.807% are low. Item 17 requires students to determine the amount of calcium acetate required to prepare a buffer solution with pH = 8. Most students are out of category because students do not change the pH to pOH first, so the calculation of [OH$^-$] is incorrect. Item 20 requires students to be able to determine the pH of a buffer solution previously carried out by titration between H$_2$SO$_4$ and NaOH. The student writes the reaction between H$_2$SO$_4$ and NaOH correctly, but the reaction equation is not synchronized. Therefore, it results in calculating the concentration of the NaOH solution and the pH of the buffer solution incorrectly.

4. Conclusion
Based on the results of research and discussion, it can be concluded that students' concept of understanding on buffer solution material is not intact due to several factors. Based on the results of interviews with students found that the lack of understanding caused mainly by students. The findings of this study are students only memorize the material, such as memorizing acid, base, and salt. Students do not understand conjugate acid and conjugate base. Students are not able to relate between the macroscopic, submicroscopic, and symbolic aspects due to the weakness of the students' ability to interpret the explanation from the form of symbolic to submicroscopic and vice versa. Understanding the concept of buffer material from the results of this study shows that as many as 47.061% understand, 29.868% less understood, 12.763% misconception, and 10.307% do not understand.

Acknowledgment
This research was funded by The Ministry of Research, Technology and Higher Education Republic of Indonesia.

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