Scientific Approach and Inquiry Learning Model in the Topic of Buffer Solution: A Content Analysis

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Abstract. Many concepts in buffer solution cause student’s misconception. Understanding science concepts should apply the scientific approach. One of learning models which is suitable with this approach is inquiry. Content analysis was used to determine textbook compatibility with scientific approach and inquiry learning model in the concept of buffer solution. By using scientific indicator tools (SIT) and Inquiry indicator tools (IIT), we analyzed three chemistry textbooks grade 11 of senior high school labeled as P, Q, and R. We described how textbook compatibility with scientific approach and inquiry learning model in the concept of buffer solution. The results show that textbook P and Q were very poor and book R was sufficient because the textbook still in procedural level. Chemistry textbooks used at school are needed to be improved in term of scientific approach and inquiry learning model. The result of these analyses might be of interest in order to write future potential textbooks.

1. Introduction
Buffer solution is a solution that resists changes in pH when small amounts of acid or base are added. There are two kinds of buffer that are acidic buffers (pH <7) and basic buffers (pH>7). The component of buffer solutions are weak acid and its conjugate base or vise versa [1] [2] [3] [4]. If small amount of strong acid add to acidic buffer, H+ ions from strong acid will neutralize by conjugate ions so there will be no change in pH. In other hand, if small amount of strong base add to acidic buffer, OH⁻ ion from strong base will combine with H⁺ ion to form H₂O, so it will not change the pH [4]. Calculating the pH of a buffer used Henderson-Hasselbalch equation, that is: pH = pKa + log [conjugate][weak acid] [3].

Concepts of buffer solution had been taught in science class especially in chemistry. Many students assume that buffer is one of difficult concept in chemistry [5]. Buffer solution relate with other concept such as chemical equilibrium, acid/base chemistry, the particulate nature of matter, chemical reactions, stoichiometry, solution chemistry [6]. To learn buffer solution concepts, student must understand about macroscopic, microscopic, and symbolic perspective in that material. Student must relate the macroscopic to microscopic properties of buffer solution [7]. Many teachers still used traditional approach in learning. They taught all material and students only listen and read textbook. However, if students do not understand the concept from those courses, they will not be able to understand their textbook [8].

From the literature was found, many concepts in buffer solution cause student’s misconception [5] [9] [10]. Some students define that buffer solution is a solutions maintaining neutral pH (pH=7) [5] [10] [11]. Other misconception that found about component of buffer solution, they assume that buffer consist of any acid and any base not necessarily a weak/strong, in any proportion [5]. Other student assumed that buffer is formed by an acid and its salt [10] [12]. Misconceptions can occur because textbook as a source of learning and teaching method [13]. Many textbooks only presented materials
without give opportunities for student to explore the material and teacher used textbook as a dominant instructional tool in science education. So that science textbooks have great influence over how content is delivered and even what should be taught. To reduce misconception, textbook should elaborate instructional strategy for teaching to provide idea about how to explore specific concepts, present microscopic properties of concept, and present the concept step by step that contain details instructions so students more understand the concept that is scientific approach.

Scientific method is a learning method that arranges into steps or stages which contains instructions for conducting students learning [14]. Scientific method can be used to understand about science and eliminate student's misconceptions [15]. Since 2013, Indonesian teachers must use scientific approach in learning according to the 2013 curriculum. They are five activities: observing, questioning, experimenting, associating, and communicating. By using scientific approach, student can be active in learning [14].

The scientific approach can be integrated into several learning models. One of learning models that can be integrated in scientific approach is inquiry-learning model. Inquiry learning model defines as a process for obtaining information through observation or experimentation to solve a problem by using critical and logical thinking ability. The step of inquiry learning model are orientation, defining the problem, making hypotheses, data collecting, testing hypothesis, writing conclusions [16][17]. Inquiry model has many benefits, such as improve the opinion and scientific thinking skills [18], improve performance and reduce anxiety students assume the chemical is a difficult subject [19]. In addition, inquiry learning model can also reduce the misconceptions[20].

From this problem, analyze textbook’s contents were needed. This analyze is needed a research technique which can make replicable and valid interference from data to their content that is content analysis [21]. From the literatures, content analysis was used by coding the manifest content and counting the frequency of words, photographs, drawings, and questions by cognitive level [22]. It is used also to analyze science textbooks content on the basis of the achievement motive construct and its theory [23]. The other functions is to compare the responses expected of students who used one science text to those expected of students using other science texts [24]. In this, the content analysis was used to analyze chemistry textbooks on the basis of scientific approach and inquiry learning model step and its theory. Content analysis of chemistry textbooks with scientific approach and inquiry learning model in the concept of buffer solution is still rare. Therefore, this research still needs to be done because textbook is one resource that is widely used for teaching and learning. From introduction presented above, this study aims to determine textbook compatibility with the scientific approach and inquiry learning model in the concept of buffer solution.

2. Method
Method of this research was content analysis, which used a coding qualitative and quantitative analysis. We analyzed three high school chemistry textbooks grade 11 in the concept of buffer solution, labeled as book P, Q, and R that used in Indonesia learning. The data collecting technique used documentation method. Data obtained through this method is data regarding content analysis by identifying the compatibility of textbooks with scientific approach and inquiry learning model in the concept of buffer solution. The research instrument used in this study is scientific indicator tools (SIT) for analyzing the compatibility of textbooks with scientific approach and Inquiry indicator tools (IIT) for analyzing the compatibility of textbooks with inquiry learning model in the concept of buffer solution to collect the relevant data for content analysis. This instrument developed based on the definition of each component of scientific approach and inquiry learning model for analysis textbook compatibility with scientific approach and inquiry learning model. Scientific indicator tools (SIT) and Inquiry indicator tools (IIT) in the form of table consisting of elements of scientific approach or inquiry learning models in the first column, the second column shows the characteristics of elements, third and fourth column contains contents in the textbook which is compatible or not. From this analysis will get information about compatibility of textbooks with scientific approach and inquiry learning model in the textbook. This study is used triangulate technique to check the validity of data. The data obtained from the analysis were tested again by involving lecturers and peers. After that, calculate the percentage of compatibility by Eq.1 for scientific approach, Eq.2 for inquiry learning model and categorize accordance in Table 1.1.

\[
\%PS = \frac{K_S}{K} \times 100\%; \quad \text{.........................Eq.1}
\]
\%MI = \frac{SS}{ST} \times 100\%; \quad \text{.........................Eq.2}

Where:
- \%PS: Percentage of scientific approach
- KM: The number of the compatible components
- K: The number of total components
- \%MI: Percentage of inquiry learning model
- SS: Number of appropriate syntax
- ST: Total syntax

| Value\% | Percentage of Compatibility |
|---------|----------------------------|
| 81 <\% \leq 100 | Very Good |
| 70 <\% \leq 80 | Good |
| 41 <\% \leq 69 | Sufficient |
| 21 <\% \leq 40 | Poor |
| \leq 20 | Very Poor |

3. Result and Discussion

From the analysis above, at learning indicator definition of buffer solution: textbook R has presented the observing, questioning, experimenting, and communicating activity. It presents the issue: “if 10 mL of HCL 0,1 M added to 100 mL of H2O made change in pH from 7 to 2 and if 11 mL of NaOH 0,1 M also added, pH will be 11”. Is there any solution that can maintain pH if small amount of acid or base is added? This question can provokes students to make more inquiries and can make students’ curiosity increase. To answer this problem, this textbook shows an experiment used any solution such as: HCL 0,1 M, NaOH 0,1 M, CH₃COOH 0,1 M, CH₃COONa 0,1 M, NH₄Cl 0,1 M, NH₄OH 0,1 M, and universal indicator. This experiment will be found various mixtures which can change in pH and resist change in pH when amount of acid or alkali added. Then students are given the opportunities to interpret of data and so that students can write conclusion of what is buffer solution, what is different the buffer solution and other solution. In textbook shows “buffer solution is a solution which resists changes in pH when small amount of acid or base is added”. Textbook P directly shows the definition of buffer solution as “a mixture of substance that can maintain change in pH” without used five activities of scientific approach.

Textbook Q presents the illustration to observing activities about “0,1 mL HCl 1M is added to one liter of water will change in pH from 7 to 4 but 0,1 mL HCl 1M is added to one liter of sea water will change in pH 8,2 to 7,6. Sea water is a buffer solution. Then students are invited in experiment activities to differentiate which is buffer solution and not buffer solution. Furthermore students are given the opportunities to interpret of data from experiment and write conclusion about define of buffer solution. Its textbook presents that buffer solution as a solution which can maintain change in pH”. Textbook Q defines of buffer solution as a solution which changes in pH. It can make student’s misconception because this statement less complete. Buffer solution can resist change in pH only when small amount of acid or base is added. If much acid or base is added, pH of buffer solution will change according to the amount of acid or base is added.

Second learning indicator is about component of buffer solution. Textbook P shows illustration which describe component of buffer solution. “Buffer solution can resist change in pH when small amount of acid or base is added. Buffer solution contains two solutes as a weak Bronsted acid and the other as a weak Bronsted base. These two solutes form a acid- conjugate base pair. If the acid is a molecule, the base of the conjugate is the dissolved salt of the acid”. But after that textbook directly presents component of buffer solution, “It concluded that component of buffer solution is weak acid or base and its conjugation”. Textbook Q directly present component of buffer solution is weak acid or base and its conjugate. While textbook R present the concepts with five activities of scientific approach. Observing and questioning activity can be found when the textbook shows issue “when small amount of HCl and NaOH are added to mixture of CH₃COOH/CH₃COONa and mixture of NH₄OH/NH₄Cl, pH of solution is relatively constant, but if large quantities of HCl and NaOH, pH will change according to HCl or NaOH are added. From the illustration above, what components are contained in the buffer
solution?" This illustration makes students interested to learn this material. Then, experimenting activity can be found when this textbook explains the result of illustration. From the illustration above there are two mixtures which can role as buffer solution, CH3COOH/CH3COONa as an acidic buffer because pH of solution <7. In this mixture CH3COOH isn’t ionization because of weak acid and CH3COONa will ionization as CH3COO− and Na+, can be seen in (A).

\[ \text{CH}_3\text{COOH (aq)} \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}^+(aq) \]  

\[ \text{CH}_3\text{COONa (aq)} \rightarrow \text{CH}_3\text{COO}^-(aq) + \text{Na}^+(aq) \]

It can be concluded that mixture of weak acid (CH3COOH) and its conjugate acid (CH3COO−) are called an acidic buffer solution. Its mixture can make from weak acid and its salt or a large amount of weak acid and strong base. NH4OH/NH4Cl as basic buffer because pH of solution >7. NH4OH is obtained from NH3 gas and water. NH3 is a weak base so it cannot ionization. While NH4Cl will ionization as NH4+ and Cl. Therefore basic buffer contains weak base and it’s conjugate.

In learning indicator how buffer solution works, textbook P directly presents all material “Buffer solution works relate with the phenomenon of common ion effect. An example of this effect is when CH3COOH is dissolved in water and then CH3COONa added to the solution will form the reaction such as (B).

\[ \text{CH}_3\text{COOH (aq)} + \text{H}_2\text{O (l)} \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}_3\text{O}^+(aq) \]  

According to the Le Chatelier principle, addition of CH3COO− ion will shift equilibrium to the left”.

Textbook Q also directly presents all material without used observing, questioning, experimenting, associating, and communicating activity. While, textbook R directly presents all material. Buffer solution can resist change in pH is the result of the equilibrium between a weak acid and its conjugate. The reaction can be seen in (C).

\[ \text{HA (aq)} \rightleftharpoons \text{H}^+(aq) + \text{A}^-(aq) \]

If acid added to the solution, H+ ion from acid will react with A− in system. But if base added to the solution, OH− ion from base will react with H+ to form H2O. It condition also occurs when basic buffer is adder acid or base.

Concept of function of buffer solution is not present in textbook P. Textbook Q directly presents all material without used five components of scientific approach. Textbook R presents the function of buffer solution concept with five activities of scientific approach. In observing activities, textbook R invites students to observe the buffer solution in everyday life. Then student must make question about that phenomenon. After that, student must collect material from other source to explain the answer and write conclusion about it. Finally, textbook also presents all material the function of buffer solution in Intracellular is H2PO4-/HPO42−, protein is amino acid and blood is H2CO3/HCO3−. If an acid is added to blood, H+ ion from acid will react with HCO3− ion which can be seen in (D).

\[ \text{H}^+(aq) + \text{HCO}_3^-(aq) \rightarrow \text{H}_2\text{CO}_3(aq) \]  

While, if a base substance is added to blood, OH− ion will react with H2CO3 as (E).

\[ \text{OH}^-(aq) + \text{H}_2\text{CO}_3(aq) \rightarrow \text{HCO}_3^-(aq) + \text{H}_2\text{O (l)} \]

Calculating pH of buffer solution, Textbook Q only presents the formula to calculate pH of buffer solution using equation 3.

\[ [\text{H}^+] = \text{Ka} \times \frac{[\text{mole of weak acid}]}{[\text{mole of conjugate}]} \]  

\[ \text{pH} = -\log [\text{H}^+] \]

\[ [\text{OH}^-] = \text{Ka} \times \frac{[\text{mole of weak based}]}{[\text{mole of conjugate}]} \]

\[ \text{pOH} = -\log [\text{OH}^-] \]

\[ \text{pH} = 14 - \text{pOH} \]

While, in textbook P and R students are involved to find pH formula. The observing, questioning, experimenting, associating, and communicating activities have showed in textbook. Students look at the equilibrium reaction of weak acid and its conjugate as (F).

\[ \text{HA (aq)} \rightleftharpoons \text{H}^+(aq) + \text{A}^-(aq) \]  

From the reaction (F), students must relate that reaction with Ka according to equation 4.

\[ \text{Ka} = \frac{[\text{H}^+] \times [\text{A}^-]}{[\text{HA}]} \]  

So, It can be determined like equation 5.
\[ [H^+] = K_a \times \frac{[HA]}{[A^-]} \] \hspace{1cm} \text{Eq. 5}

After that students relate concentration with mole according to equation 6.

\[ \text{Concentration} = \frac{\text{mole}}{\text{volume}} \] \hspace{1cm} \text{Eq. 6}

Then it can be written like equation 7.

\[ [H^+] = K_a \times \frac{\text{mole of HA}}{\text{mole of } A^-} \times \frac{\text{volume}}{\text{volume}} \] \hspace{1cm} \text{Eq. 7}

But formulate of pOH directly presents in this textbook.

Generally, textbook P and Q are still very poor categorized of scientific approach only 12% and 16% activities of scientific approach contains in this textbook. In this textbook only contains observing activities but other activities (questioning, experimenting, associating, and communicating) must be added in this textbook. Textbook R is better than textbook P and Q. It is sufficient categorized with 68% activities of scientific approach. In learning indicator how buffer solution work is not contain scientific approach activities. This results parallel to the literature, textbooks for the most part content to provide only a very general outline of scientific method [25]. Therefore, teachers should add the activities that are compatible with the scientific approach that have not been presented in the textbook, so student can be more understand about these concepts and active in learning.

The textbook compatibility data with inquiry learning model consist of Orientation, formulating the problem, formulating the hypotheses, data collecting, evaluating the hypothesis, writing conclusion). Textbook P and Q only contain about 27% and 33% step of inquiry learning model. It is included poor categorized. Textbook R only contains 73% step of inquiry learning model. This is better than textbook R and Q. It is included good categorized. From the analyzed, the steps of the inquiry learning models have not been presented in all of textbooks especially formulating the hypotheses, data collecting, and evaluating the hypothesis steps. This results parallel to the literature, textbooks for the most part content to provide all material without give opportunities for student to explore materials [8] [26].

Textbook R has contained six step of inquiry learning model in learning indicator define of buffer solution, component of buffer solution, and function of buffer solution. However, in learning indicator how buffer solution works and calculating pH of buffer solution only contained orientation and writing conclusion steps. Textbook P and Q only contain orientation and writing conclusion steps in all of learning indicator, but textbook P is not present function of buffer solution concept.

4. Conclusion

The Textbooks only presented material-related subject. Whereas in the textbooks should present five levels: observing, questioning, experimenting, associating, and communicating activities according to the scientific approach. The levels of orientation, defining the problem, making hypotheses, data collecting, testing hypothesis, and writing conclusions according to inquiry learning model is another content that are needed to have students with critical thinking. So, it can be used as a guide in learning because textbooks still play an important role in chemistry learning.

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