Concept cartoons for diagnosing student’s misconceptions in the topic of buffers

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Abstract. Student’s misconceptions have been concerned over twenty years in the chemistry education research. It influences students to learn new knowledge and gain a correct concept. The buffer solution is found as a difficult topic due to student's misconception. However, the research related this subject are still rare. Concept cartoon has been used as one of the effective tools to diagnose misconceptions. This study aims to identify the effectiveness of concept cartoon to diagnose them. The concept cartoon consists of three concept questions. 98 students of grade 11 as respondents of this research and followed by interview for selected students. The data obtain of the study are analyzed by using a scoring key. The detected misconceptions are about what buffers do, what buffers are, and how buffers are able to do what they do. Concept cartoon is potential as a basic tool for remedial teaching.

1. Introduction
Over the past decades, students interest and achievement in chemistry have declined [1]. Many students assumed that chemistry is a challenging, complex, and an abstract subject that requires particular intellectual to be understood [2] [3] [4] [5]. There are many reasons chemistry difficult to learn. The first reason is teacher used a regularly common teaching method that makes student passive, not thinking, the information receiving role [4], and other reason student knowledge of chemistry is incomplete and incoherent. On the other hand, many students merely memorize chemistry concepts without profoundly learning them [6]. Students need to understand into sub-micro levels where the characteristic of substances is learned regarding the unseen (atoms, molecules, ions) and recorded in some representational level (symbols, notation) to learn chemistry [7]. Moreover, students do not come to the classroom with blank slates, but they have had a previous concept from their experiences which is described as pre-concept, and they used it to learn new ideas. When student’s pre-concept are different from the views of scientist that called misconceptions [8]. Misconception not only from the students but also commonly caused by inappropriate teaching methods, materials, and solves for a full understanding that can be called as school-made misconceptions [9]. Deficiency ability of students in science makes occurrence of misconceptions. It happens to students at all levels of school [10]. In chemistry, many concepts that are frequently misapprehended especially in buffer solution. When understanding of buffers, students must relate the concept from macroscopic, microscopic, and symbolic perspectives [7]. They also must relate to another concept such as chemical equilibrium, acid/base chemistry, the particulate nature of matter, stoichiometry, chemical reactions, solution chemistry [2] [11]. However, in fact many research find that misconceptions occur in chemical equilibrium [12] [13] [14] [15] [16] [17] [18] and acid/base chemistry [2][19][20] [21] [22]
While students’ misconceptions in buffer solution find in some journals which are presented in Table 1.1.

Table 1. Student’s Misconceptions in Buffer Solution

| Sub Topic                             | Description                                                                                   |
|---------------------------------------|----------------------------------------------------------------------------------------------|
| Definition of buffer solution          | Buffer is a solution that contains an acid and its salt; a reactions can increase or decrease the acidity [25] |
| Component of buffer solution          | -Buffer is formed from two chemicals that are any acid and base, in any proportion, not necessarily a weak acid/base and its conjugate in approximately equal amounts [11]  
                                           -Buffer is formed by a weak acid and its salt, not its conjugate base [26] [27] |
| How do buffer solution work            | Buffers maintaining neutral pH (pH = 7), if acid/base is added to buffer solution [26] [27] |
| pH of buffer solution                  | The strength of buffer solution (capacity) is determined by the strength of its components acid and base. A buffer solution has a strong base and a strong acid in a solution that can compensate. pH of a weak acid in solution is equal to its pKa [11] |

The misconception is one of the problems in learning especially in chemistry. It must be removed because it can disturb the student for learning new knowledge. Many ways can be used to explore student’s misconception, but in this research, we use concept cartoon. Concept cartoon is visual tool consist of three or more characters (one of the characters proposes right ideas, and other characters show wrong ideas) whereas it discusses a subject of concept in daily life [5] [28] [29]. Concept cartoons as a strategy to incorporate and integrate five-knowledges, they are pedagogy, content, context, research, and knowledge (PCCRK) [30]. Cartoon concept can make student inquires their knowledge [31]. Furthermore, concept cartoon can be used as a tool to identify students’ misconceptions and effective for finding out student’s idea without affecting of other ideas [5] [32] [30] [33] [29] [34] [35] [36]. Considering the fact of concept cartoons, it can find out student ideas and identify students’ misconceptions. Thus, it is expected that student’s misconceptions of the buffer solution can be detected with it. Although, there are many types of research in literature related to use of concept cartoon in physic, chemistry, and mathematics education. However, the researches of concept cartoons in detecting students’ misconceptions of buffer solution are highly limited. This research aimed to identify the effectiveness of concept cartoon on detection student’s misconception in the topic of buffer solution.

2. Method
This research is mixed-method study. There are three concept cartoons prepare related to buffer solution that developed based on literature and curriculum of the chemistry. Two lecturers who had some experience about concept cartoon to consult in the preparation of the concept cartoon and check the content validity, both regarding content and it’s compliance with the rule of developing concept cartoons. The concept cartoons produced is applied to 98 participants attending to the 11th grade of High School in science program 2016 to 2017 second semester in three school categories high (labeled as A), medium (labeled as B), and low (labeled as C).

In this research, Teacher has made the instrument of true concept consist of the definition of buffer solution, the component of buffer solution, how do buffer solution works, function of buffer solution and calculating the pH of buffer solution to check student’s concept. The buffer solution is taught in three meeting. In the first stage, the teacher gives the general information about definition and component of buffer solution. The second, how do buffer solutions works. The last, calculating the pH of buffer solution. For this purpose, concept cartoon is used to detect misconceptions related to the
concept. The concept cartoons are presented in the student’s worksheet. In the first part, students are asked to choose a character that they think correct in the concept cartoon and explain their reasons for selecting the characters in the second part. Then, discussing about their ideas and presenting their ideas. At the same time, the teacher asks questions that encouraged the students to be active participants in learning and help student to find the correct concept. Thus, the student will change their conceptions.

The answer in the first and second parts are analyzed using an answering key which developed by the researchers to determine their understanding of the concepts [33]. Then classified according to the criteria of student’s level knowledge can be seen in Table 1.

| Answering                          | Criteria        |
|-----------------------------------|-----------------|
| Correct Answer-Correct Explanation| Understanding   |
| Correct Answer-Partially Correct Explanation| Partial understanding |
| Correct Answer-wrong Explanation  | Misconception   |
| wrong Answer-Correct Explanation  | Misconception   |
| wrong Answer-wrong Explanation    | Not understanding|

The student who identified misconceptions will be interviewed. After that, calculating the percent of student's level of knowledge according to the equation (1),

\[
\text{\% student’s level of knowledge} = \frac{\text{number of student for each criteria}}{\text{total of student}} \times 100 \quad \ldots \ldots \ldots (1)
\]

3. Result
The first concept cartoon discusses the definition of buffer solution. Concept cartoon question “How is pH in mouth if food that we eat contains excessive acid?”. The examples of first concept cartoon can be seen in figure 1 below.

**Example of Reasons:**

a. pH of a solution is constant because buffer solution is a solution that resists changes in pH when acid or base is added.

b. pH of solution <7, because pH in the mouth is acid, if excessive acid is added, pH in the mouth will constant, buffer solution can resist change in pH

c. pH of solution =7, solution will be neutral, because buffer solution can make the solution neutral

d. pH of solution >7, solution will be base because the properties of buffer solution must change to resists changes in pH when excessive acid is added
The result of the interview (T as teacher and S as a student with misconceptions) is presented below.

T: Which character do you think is correct to the question “How is pH in the mouth if the food that we eat contains excessive acid?” Why do you choose that?

S2: None. I think pH in mouth is acid and buffer solution can resist changes in pH when acid is added in any amount, so pH value < 7

T: Are you sure?

S2: Yes, of course, because buffer solution contains a component that can resist change in pH

T: How about you? What is your answer?

S3: I think None. Because substance which added is acid, so the solution becomes acid and pH value < 7

Second, concept cartoon about how do buffer solutions works. The concept cartoon question “how does buffer work maintaining a constant blood pH when the small amount of base added?” The example of second concept cartoon can be seen in figure 2.

Example of Reasons:

a. Increasing the amount of CO₃²⁻ ions because base will react with CO₃²⁻ ions
b. Reacting base with water, because water can dissociate to H⁺ ion and OH⁻ ion and base will react with H⁺ ion, so pH of solution will constant
c. Excreting base from the body so base will be removed from body
d. Reacting base with acid to produce salt and water. Because base always reacts with an acid, so pH=7, the properties of solution become neutral. adding base will not cause shifting the equilibrium

The result of the interview (T as teacher and S as a student with misconceptions) is presented below.

T: Which character do you choose S2 to the question “how does buffer work maintaining a constant blood pH when the small amount of base added?”

S2: None. I think in the blood, base react with acid producing salt and water. It makes pH of solution = 7 and solution will be neutral.

T: Are you sure?

S2: Yes, I am sure. Adding base also will not cause shift the equilibrium, so the pH is constant

T: How about you S3? What is your answer?

S3: I think None. In the blood, the small amount of base is added will react with acid so the base will remove and pH value in the blood is constant.

Third, concept cartoon about calculates the pH of buffer solution. The concept cartoon questions “Whether the volume of the solution affects the capacity of a buffer solution?” The example of third concept cartoon can be seen in figure 3.
Example of Reasons:

a. It does not affect because the concentration of weak acid/base and its conjugation that used in the Henderson-Hasselbalch equation. So, capacity of buffer solution is only affected by concentration.

b. It depends on the substances because not all substances can be reacted with an acid or based is added.

c. It affects, because if the volume of buffer solution is large. The buffer capacity also will large.

d. It affects because volume of buffer solution can be affected by acid/base is added.

Figure 3. Concept Cartoon About Calculating The pH of Buffer Solution

The result of the interview (T as teacher and S as a student with misconceptions) is presented below.

T: Which characters do you choose to the question “whether the volume of the solution affects the capacity of the buffer solution?”

S2: None. I think volume of solution and the strength of its components acid and base affected the capacity of buffer solution

T: Do you think it is correct?

S2: Yes, I do because strong acid and base can resist the change pH

T: How about u S3?

S3: I think None, but I don’t understand about it

The result of % student’s level knowledge of concept cartoon 1, 2, and 3 can be seen in Table 2.

Table 3. The Result of Student’s Level Knowledge of Concept cartoon 1, 2 and 3

| School | Criteria | Understanding (%) | Partially understanding (%) | Misconception (%) | Not understanding (%) |
|--------|----------|-------------------|-----------------------------|-------------------|----------------------|
|        |          | 1 2 3             | 1 2 3                       | 1 2 3             | 1 2 3                |
| A      |          | 31,3 12,5 31,3    | 15,6 15,6 21,9             | 46,9 40,6 34,3   | 6,2 31,3 12,5       |
| B      |          | 20,6 10,9 30,4    | 11,8 13,8 15,7             | 44,1 36,3 32,4   | 23,5 39 21,5        |
| C      |          | 21,9 6,3 21,9     | 9,4 9,3 21,9               | 40,6 34,4 34,3   | 28,1 50 21,9        |

4. Discussion

The research conduct, the concept cartoon which is used as detection student’s misconception tools relates to buffer solution. Concept cartoon is used to stimulate discussion before, during, and after the investigation to arrange conclusion. There are various ways of using concept cartoon in sciences courses. Researcher uses concept cartoon as instructional material in science courses in the form of concept cartoon worksheet. Concept cartoons need to prepare and design following the characteristics: minimal amounts of text, the scientific idea applied in everyday situations, the alternative ideas put forward based on research that identifies common areas of misunderstanding. The scientifically acceptable viewpoints will be included among the alternatives. The alternatives put forward all
appearing to be of equal status. Thus learner cannot work out which option is correct from the context [29].

Observation of research shows that students prefer enthusiastic in the learning. Thus, the lesson becomes more interactive and student-centered as students are actively involved in their learning. At the beginning of new lesson, the concept cartoon appears to be an effective stimulus for student to create their idea and focus on learning. They must choose one of the characters that true statements and discuss what they think about the ideas given. Then explain why they have those ideas. After that, they present their argument, and other students provide their argument, so it can motivate the student in discussing and increasing student’s understanding. During the discussion, they look comfortable to express their idea. According to interview result, using concept cartoon in learning makes student enjoy their conversation, enhance their motivation, and probe student’s misconception. These findings are parallel to the ideas of Gafoor [5] who state that concept cartoon makes student increasing their understand, attention and interest, improve motivation toward learning.

The first, concept cartoon shows the definition of buffer solutions. The buffer solution is a solution that resists changes in pH when small amount of an acid or alkali is added. The question of concept cartoons “How is pH in mouth if food that we eat contains excessive acid? The correct answers are pH of solution <7; solution will be more acid because of the amount of [H+] increase. The average pH range for saliva is considered to 5.6 to 7.9 according to the International Journal of Drug Testing. If excessive acid is added, then the amount of [H+] will increase. In this research, there are 46.9% students of A, 44.1% students of B, and 40.6% students of C detected misconception. Some students assume that pH of solution <7, solution will be acid because the normal pH in the mouth is acid and buffer solution can resist changes in pH when acid is added in any amount. This misconception parallel to the research of Muttlu & Sesen [27]. Other students assume that pH of solution <7, solution will be acid because substances which added is acid then the solution become acid and pH value < 7.

The second, concept cartoon shows how do buffer solutions work. A pH buffer contains molecules that can bind to other molecules in an acid or a base to neutralize them. The question of concept cartoon is “how does buffer work maintaining a constant blood pH when small amount of base added?”. The correct answer: The components of buffer in blood are carbonic acid (H$_2$CO$_3$) and hydrogen carbonate ion (HCO$_3^-$). When small amount of bases added, base will react with carbonic acid (H$_2$CO$_3$) produce hydrogen carbonate ions (HCO$_3^-$) and water. Carbonic acid binds to the loose hydroxide molecules. In this manner, the hydroxide ion (OH-) is removed from blood, preventing the pH of blood become base. Furthermore, adding base will shift the equilibrium to the left. Thus, the amount of H$^+$ is removed, and pH is constant. In this research, there are 40.6% students of A, 36.3% students of B, and 34.4% students of C detected misconception. Many students assume that base will react with acid to produce salt and water. pH of solution = 7, solution will be neutral. Therefore, buffer can maintain a constant blood pH. Adding base will not cause shift the equilibrium. These findings are parallel to the research of Orgill & Sutherland[11]; Mutlu & Sesen, [27].

The third, concept cartoon shows calculates the pH of buffer solution. The concept cartoon question “Whether the volume of solution affects the capacity of buffer solution?”. The correct answer is the volume of solution affects the capacity of buffer solution because the capacity of buffer solution depends on mole of weak acid/base and its conjugate. The mole can be determined from concentration x volume. Thus, if amount of volume is large, the capacity of buffer solution is also large. In this research, there are 34.3% students of A, 32.4% students of B, and 34.3% students of C detected misconception. Some students assume that volume of solution and the strength of its components acid and base affected the capacity of buffer solution. These findings are parallel to the research of Orgill & Sutherland [11].

5. Conclusions
The findings of this research show that concept cartoons are practical tools to detect student’s misconception in buffer solution. Many student’s misconceptions have detected by concept cartoon. It has been remedied after investigation, discussion and interview about concept. Misconceptions find in
this research are similar to the misconception in the literature. Another finding research shows that concept cartoons can be used in science learning especially in chemistry because it makes student active in learning, increases motivate to discuss and inquire their knowledge. It is suggested that concept cartoon should be used before learning to identify student’s misconception and after learning to remove misconception. In another hand, each should give their ideas about the question of concept cartoon then brings ideas for discussion with friend.

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