Students' Conceptual Understanding of Acid-Base Titration and Its Relationship with Drawing Skills of A Titration Curve

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Abstract. The aims of this study to describe the conceptual understanding of acid-base titration and its relationship with drawing skills of a titration curve. This study uses a quantitative approach with a type of correlational descriptive one. The study has been carried out with 54 undergradute students of the Chemical Education Department at the Faculty of Tarbiyah and Teacher Training in State Islamic Institute of Tulungagung in the even semester of the 2018/2019 academic year. The data collection used test technique which is consisted of a written test and drawing skills of a titration curve using Ms. Excel. The data analysis technique used product moment correlation with the SPSS 17.0 program. The results showed that the average value of conceptual understanding in acid-base titration and drawing skills of a titration curve respectively were 53.7 (medium) and 71.4 (good) with the number of students getting above average scores respectively were 25 (46.3%) and 30 (55.6%) students. Based on product moment correlation analysis, sig = 0.000 <0.05 means that there is a significant relationship between the conceptual understanding of acid-base titration with the skills of drawing the titration curve. Furthermore, the value of r = 0.526 correlation is included in the moderate category.

Keywords: acid-base, conceptual understanding, titration, curve

1. Introduction

Acid-base material is one of the topics in chemistry which is the basic material for studying the next material those are acid-base titration, buffer solution, and salt hydrolysis (Yustiadi [9]). Acid-base material has many concepts that should be understood by students including macroscopic, microscopic and symbolic aspects. Macroscopic aspects include the identification and measurement of pH of acid-

base solutions using indicators (through changes in the colour of universal indicators). The microscopic aspects include how the mechanism of proton handover (H^+) and the transfer of electron pairs in acid-base reactions. Symbolic aspects include the calculation of algorithms to determine concentrations of H^+ and OH^-, pH of acid-base solutions, and drawing acid-base titration curves.

During the process of learning acid-base material, students often have difficulty understanding. Some research results show that students experience difficulties in macroscopic, microscopic, and symbolic aspects. ~~Research by Kousathana, et. al. [3] shows that~~ difficulties of acid-base material often occur mainly in the concept of acid-base theory, neutralization reactions, acid-base strength, and characteristics of acid-base solutions. ~~Rasmawan's [5] research shows that~~ students have difficulty in understanding the concept of acid-base, especially in calculating acidic pH, basic pH and acid-base mixture pH. Further similar research ~~conducted by Tarhan & Sesen [6]~~ shows that (1) students are still confused to distinguish or identify acid-base compounds according to Bronsted-Lowry theory with Lewis theory, (2) have not been able to identify the existence of electron handover in the reaction between acid-base compounds (Lewis's theory), and (3) students prefer to define acids and bases according to the Bronsted-Lowry theory and they have difficulty in explaining Lewis's acid-base theory. In other similar studies, Marpaung [4] states that students have difficulty in understanding the calculation techniques for determining the levels of an acid-base solution based on a titration curve, and they are less able to apply the concept of acid-base titration in daily life.

One of the factors causing the difficulties of students in learning acid-base material is that acid-base learning places more emphasis on algorithmic calculations (symbolic aspects) ~~(Widarti, et. al., [8])~~, so that they are lack in microscopic aspects. In addition, the algorithmic calculations learned are only limited to calculating the pH of acid-base solution, not yet to the skill of drawing a good and titration curve correctly.

If we look back at students' learning difficulties on acid-base material when they study in high school, there are some difficulties they experience, especially regarding acid-base titration. The research results of Buchori, et. al. [1] showed that (1) 89.2% of students had difficulty determining the end point of a titration using an acid-base solution, (2) students did not understand the characteristics of the end point, and (3) most students assumed that the end point of the titration is the same as the equivalent point. Similar research was also carried out by Utami [7] and the results showed that (1) students with high ability, could not answer correctly about the concept of the titration principle and draw acid-base titration curves (equivalent point, end point of titration), and correlating the volume of NaOH added to the pH of the solution in the form of an acid-base titration curve, (2) students with moderate ability cannot answer correctly about the concept of the principle of acid-base titration, determination of the concentration of acetic acid in vinegar, pH of the buffer solution and pH of the solution when it occurs hydrolysis process, and (3) students with low ability cannot answer correctly about the concept of the principle of acid-base titration, pH of weak acid solution, pH of the buffer solution, pH of the solution during the hydrolysis process, pH of strong base solution, and analysis of acid-base titration curve.

Furthermore, Utami's [7] research shows that (1) students experience misconceptions in studying acid-base material, namely in the sub concept of neutralization reaction, acid-base indicator, equivalent point, end point of titration, hydrolysis, and ionization reaction weak acids, (2) students also find difficult material (troublesome knowledge) in calculating the pH of the solution at each stage of acid-base titration, understanding the relationship between weak acids and their conjugate bases in forming buffer solutions, and linking the pH of the solution to the volume of base solution added in

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the form of an acid-base titration curve, and (3) the existence of a threshold concept, which is a weak acid ionization reaction and a chemical equilibrium constant. These results are supported by research Hadinugrahaningsih, et. al. [2] which shows that the biggest misconceptions experienced by students occur in the concept of the amphoteric nature of water that is equal to 85.31%, and the concept of acid strength (pH) (75.62%). If misconceptions on acid-base material continue to occur without treatment, it could be that at the tertiary level there will also still be a misconception of the concept.

Based on this description, acid-base learning should not be focused on symbolic aspects (algorithmic calculations) alone, but must also be balanced with macroscopic and microscopic aspects. In this study, researchers wanted to identify the understanding of State Islamic Institute of Tulungagung students on the acid-base titration sub topic. In addition, through the Computer Chemistry Fundamentals course, researchers want to find out how students' skills in depicting acid-base titration curves. Thus, the researcher took the title of the study "Students' Conceptual Understanding of Acid-Base Titration and Its Relationship with Drawing Skills of A Titration Curve."

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2. Method

This study uses a quantitative approach with a type of correlational descriptive one. The study has been carried out with 54 undergradute students of the Chemical Education Department at the Faculty of Tarbiyah and Teacher Training in State Islamic Institute of Tulungagung in the even semester of the 2018/2019 academic year. The data collection used test technique and semi structured interview.

The test consisted of a written test to measure the students' conceptual understanding of acid-base titration and a skill test drawing the titration curve using Ms. Excel. The research instruments was an essay test that modified from National Science (Chemistry) Olympiad of Senior High School on Regency / City Selection level in 2018. Here is the written test given to students.

20.0 mL of 0.01 M acetic acid solution is titrated with 0.01 M sodium hydroxide solution using two types of indicators: methyl red (pH 4-6 / red to yellow) and phenolphthalein (pH 8-10 / no colored to red). It is known that K_a acetic acid = 1 x 10^{-5}.

a. *Write the complete reaction equation and the ionic reaction (net) on the titration. (10 points)*

b. *Calculate the pH of the solution (2 decimal places) when adding titrant solution to the appropriate volume in the table below on the answer sheet and write the pH value of your calculation results on the table. (40 points)*

No.	Volume of sodium hydroxide added (mL)	pH
1	0	
2	5	
3	10	
4	20	
5	30	

d. *From this graph, determine how many mL the volume of titrant when the methyl red indicator changes the color from red to yellow right? (20 points)*

e. If the phenolphthalein indicator is used, how many mL the volume of titrant when the indicator change the color from colorless to red? (20 points)

f. From these data, which indicator is the most accurate for acid-base titration? Explain your reason! (10 points)

Afer that, the researchers analyzed of the students' answer sheet and describes the level of students' understanding. Based on the students' answers, can be known whether students able to understand the acid-base titration material or just guess the answers to the questions because they required to provide the explanations or reasons. Classification of students' understanding level of acid base titration material as given in Table 1.

Table 1. Classification of students' understanding level and drawing skills of titration curve

| Percentage (%)	Criteria
81-100	Very Good
61-80	Good
41-60	Medium
21-40	Low
0-20	Very Low

The data analysis technique to know the relationship between students' conceptual understanding of acid-base titration with their drawing skills of a titration curve used product moment correlation with the SPSS 17.0 program. Table 2 below shows the interpretation of Pearson correlation coefficient values [10].

Table 2. Interpretation of Pearson correlation coefficient values

Interval coefficient	Relationship level
0.80-1.000	Very strong
0.60 – 0.799	Strong
0.40 – 0.599	Moderate
0.20–0.399	Weak
0.00–0.199	Very weak

3. Results and Discussion

The results showed that percentage of level of understanding of acid-base titration material obtain from written test seen from the indicator are summarized in Figure 1.

Figure 1. Level of conceptual understanding of acid-base titration
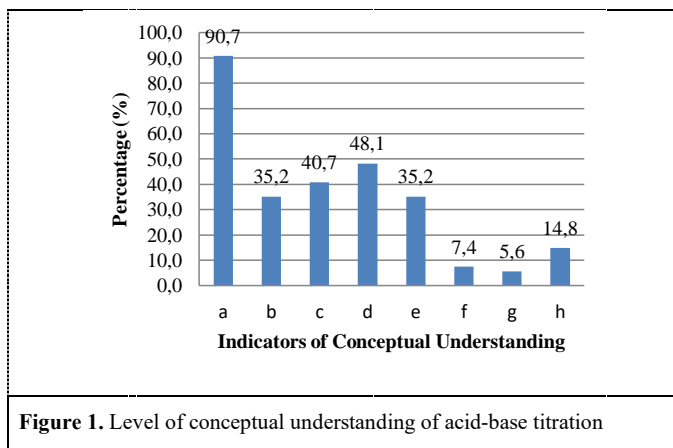
Note:

a. equalizing the reaction equation

b. pH calculation of CH_3COOH solution (weak acid)

c. buffer pH calculation

d. calculation of the pH of hydrolyzed salt

e. calculation of the pH of the NaOH solution (base)

f. calculation of the volume of titrant when the indicator of methyl red changes the color of solution

g. calculation of the volume of titrant when the indicator of phenolphthalein changes the color of the solution

h. chosing the most accurate indicator for acid-base titration

According to Figure 1 above, shows that :

(a) As many as 90.7% of students have understood the concept of equalizing the reaction equation well. In the problem, write down the name of the reacting compound. Students can write the name of the compound in their chemical formula. Only a small proportion of students who do not write down the reaction equation completely, students do not include the phase of each substance.

(b) As many as 35.2% of students have understood the concept that CH_3COOH is a weak acid and can calculate the initial pH (before being titrated) using the weak acid calculation formula. This percentage is relatively low because some students assume that before titration, the pH of the solution equal with 0. Some other students consider CH_3COOH to be a strong acid so that in the initial pH calculation before being used the formula $[H^+]$ = [Acid] x valence of acid. The results of other studies also concluded that students have difficulty distinguishing between strong/weak acid and strong/weak base (Orgill & Sutherland, 2008; Pursitasari & Permanasari, 2012) [11].

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(c) As many as 40.7% of students have understood the concept of the formation of a buffer pH. When weak acid titrated with a strong base is excessive, an acidic buffer solution is produced. This percentage is relatively low because some students do not understand about the formation of a buffer solution, wrong in using the formula for the calculation of $[H^+]$ acid buffer solution, and students use the formula $[H^+]$ to calculate the pH of weak acids. The results of Sihaloho's (2013) study also showed that most students experienced errors in understanding the concept of buffer solution [12].

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(d) As many as 48.1% of students have understood the concept of hydrolyzed salt. When the weak acid titrated with a strong base right after it reacts, a hydrolyzed and alkaline salt is formed. However, most students do not write down the hydrolysis reaction equation. Some students were also wrong in determining the concentration of salt formed, because of errors in entering the value of the volume of the solution, the volume of the reactants was not added. Another error is that students assume that hydrolyzed salt is acidic, they write $[H^+]$, some other students are wrong in calculating pH because they do not look for the pOH first, but directly pH, even though the salt formed is alkaline. A student assume that pH of this solution is neutral (pH = 7). This finding similiar with a previous finding that a neutralization reaction produces a neutral solution (Schmidt, 1991; Demirciog˘lu et al., 2005; Tu¨may, 2016) [13].

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(e) As many as 35.2% of students have understood the concept of pH of a weak acid solution titrated with a strong base after passing the equivalent point, meaning that the rest are bases so they must determine $[OH^-]$. However, some students wrong in calculation of $[OH^-]$ because the volume of reagents was not added. Some other students assume that the solution of the titration results is still acidic, because what is titrated is acidic. Some students consider the titration to produce hydrolyzed salts that are basic.

(f) Students who have understood the calculation of the volume of the titrant needed when there is a change in the color of the methyl red indicator (yellow to red) was 7.4% of students. Some students have difficulty in calculation of acid-base titration because students have difficulty analyzing problems well.

(g) Students who have understood the calculation of the volume of the titrant needed when there is a change in the color of the phenolphthalein (not colored to red) was 5.6% of students . This percentage (f and g) shows that the level of understanding of students is very low. Some students guess the volume of the titrant without using calculations. This shows students do not understand which concepts can be applied to solve the problem. This problem involved several chemical concepts such as stoichiometry, solution, and pH buffer, as well as several calculation steps in the stoichiometry of solution. In addition, students also experience difficulties because they have to use a different line of thinking. Usually the problems they

often encounter are known by the volume and concentration of a solution and then are asked to calculate the pH, while in this problem they must interpret the meaning of the color change of the methyl red indicator and phenolphthalein occurs at what pH, then with a few steps they must determine the volume of the titrant.

(h) As many as 14.8% of students have understood which type of indicator is more appropriate to be used in the titration between weak acids, CH_3COOH and strong bases, NaOH by stating the reason. Some other students only answered the type of indicator correctly, but did not explain the reason.

Based on the results above of the analysis of the concept understanding of the acid and base titration material, the average value of conceptual understanding in acid-base titration and drawing skills of a titration curve respectively were 53.7 (medium) with the number of students getting above average scores were 25 (46.3%) students. Similiar to the results of previous studies by Rasmawan (2010) [5], students experience difficulties with the concepts of acids and bases, especially determining the pH of the buffer solution and the pH of the titration. In calculating pH, errors in calculations cause errors in conclusions. Conclusions on the calculation of the pH of acids, bases, can mix acids and bases. Mistakes that often occur in determining the mole of the reaction substance in determining the mole of the reaction substance in determining the acid base mixture. Errors in moles of reacting substances, especially in the mole ratio of reacting substances. another mistake in writing the coefficient of the acid-base reaction.

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To describe students drawing skills of titration curve used Ms. Excel. In this section, for the first, students are asked to complete data and perform calculations using formulas based on their conceptual understanding in acid-base titration material. In this problem students are asked to draw alkaline solutions/ strong base are titrated with acidic solutions/ strong acid. Therefore, before drawing an acid-base titration curve, students must create a calculation and a help table which shown in Figure 2.


Figure 2. The calculation and a help table of drawing skills titration curve

The student's Excel worksheet above uses formulas as follows:

a. pH of solution (G10)=IF(J10>0;14+LOG(K10);IF(J10=0;7;-LOG(K10)));

b. mmol HCl (I10)= =$C$14*F10;

c. mmol sisa (J10)=$C$11-I10;

d. konsentrasi sisa =ABS(J10/($C$10+F10))

The results showed that percentage of drawing skills of titration curve obtain from students worksheet in Ms. Excel are summarized in Figure 3.

Figure 3. Level of drawing skills of titration curve
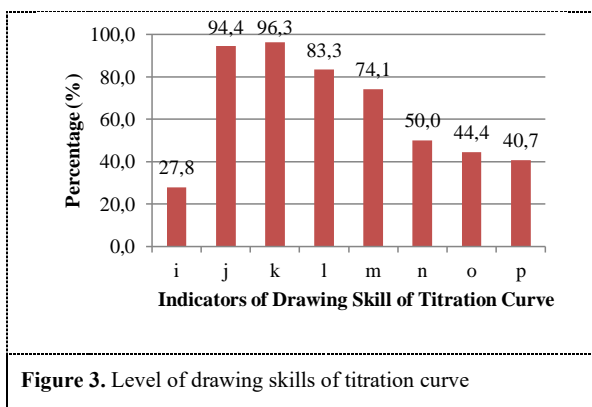
Note:

i : Reaction equation

j : write the reactant description

k : calculate the volume of the titrant

l: calculate the mmol titrant (acid)

m: calculate remaining mmol

n: calculate the concentration of the remaining solution
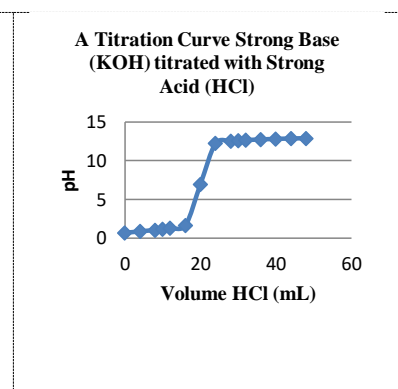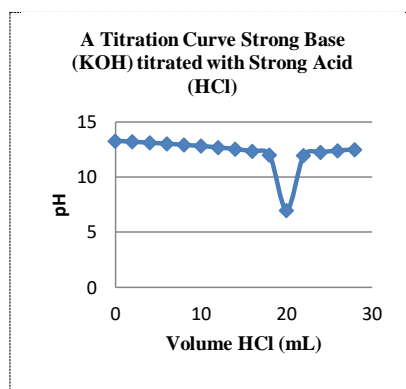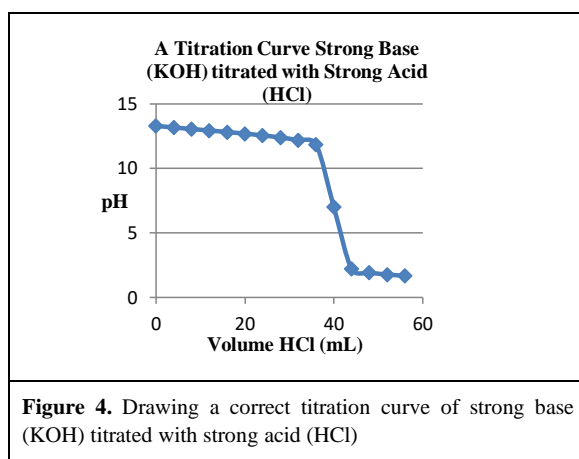
o: titration pH calculation

p: draw a titration curve

The data in Figure 3 shows that:

(i) In the first part, students are asked to write down the equation of reaction of a base titrated with acid. In contrast to the question presented earlier that is acid titrated with bases. This context is deliberately arranged differently to test students' understanding of the acid-base titration material. As many as 90.7% of students have understood the concept of equalizing the reaction equation well. This is comparable with the results of the previous analysis of Figure 1.

(j) As many as 94.4% of students have understood the reactants involved in this acid-base titration and mention the information both the volume, concentration, and mmol of the substance that is titrated correctly.

(k) As many as 96.3% of students are able to determine the volume of the titrant in accordance with the increase in volume requested in question.

(l) As many as 83.3% of students have understood the determination of the titrant (acid) mmol in the help table. Some students are not careful in entering cells in formulas. Acid mmol is obtained from the product of molarity and its volume. However, in these calculations some students enter base molarity multiplied by the volume of acid.

(m) As many as 74.1% of students have understood the calculation of the remaining mmol obtained from basic mmol reduced by acid mmol. Negative results show that the acid mmol (titrant) is excessive, while the result of 0 (zero) indicates that the acid and base are completely reacted.

(n) As many as 50% of students have understood the calculation of the residual concentration. Some students are wrong in calculation the residual concentration because they do not add up the reactant volume. In the calculation of the remaining concentrations used the ABS formula (absolute) so that if the residual mmol which is negative (mmol titrant/ excess acid) becomes positive.

(o) As many as 44.4% of students have understood the calculation of pH of acid-base titration. By observing which reactants are excess so that it affects the nature of the solution formed. However, some students were wrong in their calculations because they did not understand the nature of the solution formed so they were incorrect in entering the formula. Pursitasari & Permanasari (2012) [11] stated several reasons the difficulties experienced by students: (1) solving the problem is too long; (2) it is difficult to analyze the questions; (3) not doing the exercises. Another mistake is that students assume that the base is titrated with acid, the initial pH is less than 7 (acidic). This shows that students are less able to understand and cannot distinguish the concept between acidic solutions titrated with bases and vice versa (Figure 6).

(p) As many as 40.7% of students can draw a titration curve using Ms. Excel correctly. Some students did not write the variables on the X-axis (titrant/ acid volume) and Y-ordinat (pH of the solution). In addition, some students were also wrong in drawing the titration curve due to mistakes in entering the pH formula after the equivalent point. The pH after equivalent to the base titration with acid should be acidic because the acid is excess, but the students consider the pH of the solution to remain alkaline, the pH is above 7. Students have difficulty in interpreting a titration curve of weak/strong acid titration with strong bases (Pursitasari & Permanasari, 2012) [11]. Drawing a correct titration curve is shown in Figure 4 and the wrong ones are shown in Figure 5 and 6.

Figure 4. Drawing a correct titration curve of strong base (KOH) titrated with strong acid (HCl)

Figure 5. Drawing incorrect titration curve of strong base (KOH) titrated with strong acid (HCl)

Figure 6. Drawing incorrect titration curve of strong base (KOH) titrated with strong acid (HCl)

The average skills of drawing a student's acid-base titration curves is 71.4 (good) with the number of students getting above average scores 30 (55.6%) students. Sheppard (2006) [14] showed that in titration curve for initial non-changing value of pH, about half of the students explained that ''despite the acid having been added, the reaction had not yet started.'' One quarter said ''no reaction was occurring.

Furthermore, to determine the relationship between students' understanding of concepts in the acid-base titration material with the skill of drawing the titration curve, product moment correlation analysis is used as shown in Table 1.

Tabel 1. Correlations between Conceptual Understanding of Acid-Base Titration (X) and Drawing skills of a titration curve (Y)

		X	Y
Conceptual Understanding of Acid-Base Titration (X)	Pearson Correlation	1	.526**
	Sig. (2-tailed)		.000
	N	54	54
Drawing skills of a titration curve (Y)	Pearson Correlation	.526**	1
	Sig. (2-tailed)	.000	
	N	54	54

**. Correlation is significant at the 0.01 level (2-tailed).

The data in Table 1 can be interpreted as follows. The value of sig = 0.000 <0.05 means that there is a significant relationship between the conceptual understanding of acid-base titration with the skill of drawing the titration curve. Furthermore, the value of r = 0.526 correlation is included in the moderate category.

4. Conclusion

Based on the results of data analysis, it can be concluded that the average value of conceptual understanding in acid-base titration and drawing skills of a titration curve respectively were 53.7 (medium) and 71.4 (good) with the number of students getting above average scores respectively were 25 (46.3%) and 30 (55.6%) students. Based on product moment correlation analysis, sig = 0.000 <0.05 means that there is a significant relationship between the conceptual understanding of acid-base titration with the skills of drawing the titration curve. Furthermore, the value of r = 0.526 correlation is included in the moderate category. Students should understand the classification of strong and weak acids, strong and weak bases, pH, and distinguish the concept of buffer solution and salt hidrolysis in order to get a good conceptual understanding in acid-base titration and drawing skill titration curve. Beside that, peer learning is needed to improve mathematical skills in helping to solve chemical problems related to symbolic or chemical calculation aspects.

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