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ANALYTICAL CHEMISTRY LABORATORY QUALITATIVE ANALYSIS PROCESS EXAMINATION: LINKS BETWEEN EXPERIMENTAL DATA AND CALCULATIONS

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Abstract

Analytical chemistry and qualitative-quantitative analysis practices have an important place in chemistry education. Operations such as experimental steps in volumetric analysis, reactions, and determining the amount of matter require problem-solving and higher-order thinking skills due to mathematical calculations. Students have difficulty and anxiety in making calculations in the volumetric analysis. This research aimed to examine the ability of chemistry teacher candidates to use the data obtained from the neutralization titration experiments in the calculation of the experimental result and to analyze the effects of information obtained from experiments on solving volumetric analysis problems. The sample of the study consisted of 13 chemistry teacher candidates studying in the chemistry teaching program of a state university. The research employed a descriptive survey model. Experiment data sheets and question solutions were taken as written answers. As a result of the research, it is noteworthy that the teacher candidates have problems in calculating the results of the experiment, and this has been overcome with increasing applications.

Keywords: *Qualitative Analysis Process; Analytical Chemistry; Neutralization Titration.*

A. Introduction

Analytical chemistry is a measurement-based science used in all fields of science and medicine. Analytical chemistry involves the determination, separation, and quantification of the components that constitute an example we encounter in our daily lives. Quantitative analysis allows determining which (how much) of these chemicals are numerically present whereas qualitative analysis determines which chemicals a sample contains (Skoog et. al., 2005). Analytical chemistry and qualitative-quantitative analysis practices have an important place in chemistry education. How to obtain the amount of a specific substance in a sample by weighing the precipitated portion or measuring the volume of solution should be taught in analytical chemistry. Gravimetric analysis and volumetric analysis are still thought to form the basis (Arikawa, 2001). Color change and precipitation reactions are widely used in the recognition of substances while conducting qualitative analysis experiments (Berry, 2015).

How to obtain accurate analytical data should be taught in analytical chemistry. For this purpose, the analytical chemistry curriculum should consist of topics of chemical analysis, separation chemistry, and instrumental analysis, including experiments to learn analytical methods and techniques (Arikawa, 2001). Mistakes made in one step of quantitative analysis techniques will affect the result of the analysis. Therefore, students need to master the basic elements of traditional quantitative analysis laboratory chemical analysis (Zimmerman & Jacobsen, 1996).

Students should learn how to use an example given to them, how to determine cations in each group, whether or not they are present, perform laboratory applications involving changes in color and/or appearance, and reach results based on both theory and reactions with qualitative analysis. Students should combine theory with experimental work (Guerrero et. al., 2016). The goals set by the students for chemistry experiments are generally gathered in the affective field and are listed as follows: It is reported that they finish the experiment quickly or late, get good grades or make mistakes. In addition, students follow the steps in the experimental procedure without thinking or understanding (DeKorver & Towns, 2015).

A lack of control is perceived in the structure of laboratory lessons, and as a result, students focus only on the operations in the experimental procedure, instead of making a cognitive connection between their operations and understanding the subject (Galloway & Bretz, 2016). This situation is observed in the analytical chemistry laboratory. Curriculum application based on active activities in the analytical chemistry laboratory provides students with the opportunity to acquire knowledge practically, develops their critical thinking skills, and improves their laboratory skills by improving their self-confidence (Cavinato, 2017).

Chemistry educators draw attention to the concern in this regard based on their experience in teaching volumetric analysis (Wheeler & Kass, 1977). All these practices create anxiety against the analytical chemistry course and students have difficulty in this course. The materials used in the volumetric analysis are hard to clean and difficult to use properly. These materials (such as automatic scales) will be used in volumetric analysis with the materials that emerge with the developments in technology, and teaching chemistry will be more effective (Ramette, 2004). Operations such as experimental steps in volumetric analysis, reactions, and determining the amount of matter require problem-solving and higher-order thinking skills due to mathematical calculations.

Chemistry teachers and researchers emphasize that students have difficulty and anxiety in making calculations in the volumetric analysis (Duncan & Johnstone, 1973; Johnstone et. al., 1971). It is thought that the reason for the difficulties experienced by the students while making calculations in the volumetric analysis is due to the task components like this process and it is based on its structure (Wheeler & Kass, 1977). The problems experienced by the students in problem-solving are identified and appropriate teaching strategies can be focused on to overcome these difficulties if the difficulties inherent in the volumetric analysis task are identified. Isolating the sources of difficulties experienced by students also helps to understand how these resources affect their abilities and why they solve volumetric analysis problems (Anamuah-Mensah, 1981). Students often experience difficulties with concepts in volumetric analysis. The concept of molarity, for example. The definition of molarity and the mol/liter formula is understandable for very few students.

The concept should be concretely associated with colored substances such as concentrated and diluted orange juice instead of using colorless acid and base solutions while explaining the concept of morality to ensure the conceptual understanding of the student (Heyworth, 1998). It is ensured that the students understand the subject qualitatively well and get to the numerical procedures comfortably in this way. The difficulties experienced in the volumetric analysis have been explained in detail in the literature. The data obtained from the volumetric analysis experiments and the use of the obtained information in the problem-solving process of chemistry teacher candidates were examined in this study.

The steps followed in neutralization titration experiments for volumetric analysis also explain the steps to be used in solving volumetric analysis problems. Saving the data obtained from the experiments, writing the titration equation, converting the units, writing the analyze/ titrant effect value, calculating the result, writing the resulting unit are also used in volumetric analysis problems. This study aims to calculate the experiment results of the data obtained in neutralization titration experiments, to examine its effect on understanding the purpose of the experiment, and to investigate the use of this information in solving volumetric analysis problems.

B. Method

The purpose of this research is to determine the level of chemistry teacher candidates' ability to use the data obtained from neutralization experiments in calculating the results of the experiment and to solve problems related to the subject. The research model is a descriptive survey model. The descriptive survey model was used because the research question was to reveal the use of the data obtained from the neutralization experiments in calculating the results of the experiment and to determine the effect of this information on solving the problems related to the subject. The situation that exists in the past or still is determined as it is in the survey model (Karasar, 2013). It is carried out to identify, compare, classify, analyze, and interpret the groups and events that make up the research fields. A descriptive survey aims to explain the data about the related variables (Cohen et. al., 2007).

1. Sampling

The sample of the research consists of 13 pre-service teachers who are in the third year of the chemistry teaching program and voluntarily participated in the research. A purposeful convenience sampling method was used in the study. This sampling method offers researchers opportunities to overcome time-related problems and to be quickly and easily accessible to participants (Yıldırım & Şimşek, 2013). Although the total number of participants was 21 at the beginning, they could not participate in the study later due to absenteeism (n=8). The sample of the research consists of N=13 chemistry teacher candidates. 84.61% (N = 11) of the sample group were female and 15.39% (N = 2) were male. 8 of the teacher candidates were studying in the sixth semester while 5 were studying in the eighth semester. The age of the sample group varies between 20 and 22 years.

2. Data Collection Tools

The data of the study were collected with written responses including experimental calculations and problem-solving. Experiment data sheets and question solutions were taken as written answers. In the first part of the research, the result papers of the experiments conducted for standardization of NaOH, titration of HCl with standard NaOH, titration of H_2SO_4 were taken as written responses. In the second part of the research, the solutions and explanations of the two open-ended questions asked to reinforce the difference in the volumes spent in the experiments were taken as written answers.

3. Application Process

Analytical chemistry laboratory II course is given three lesson hours a week. Neutralization titrations, precipitation titrations, complex formation titrations, and redox titration tests are performed within the scope of the course. Neutralization titrations in analytical chemistry laboratory quantitative analysis were examined by HCI analysis with standard NaOH and H_2SO_4 determination experiments. Teacher candidates gave two experimental results sheets in the adjustment of NaOH and HCI determination. There was the calculation of standardization of NaOH on the first data sheet (Figure 1), and there was the calculation of HCI on the second data sheet (Figure 2). H_2SO_4 was determined with NaOH later in the week and the calculation was given as the third data sheet (Figure 3). Then, two questions were asked to reinforce the difference in the volumes spent in the experiments for HCI and H_2SO_4, and they were asked to solve and explain (Figure 4).

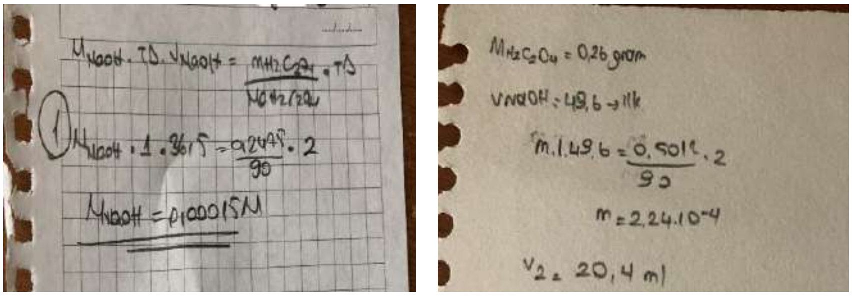

Figure 1: Example of First Data Sheets

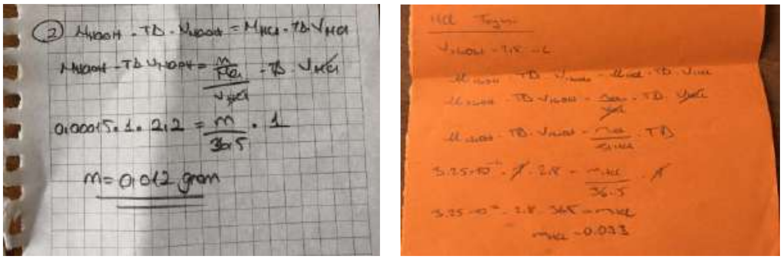

Figure 3: Example of Third Data Sheets

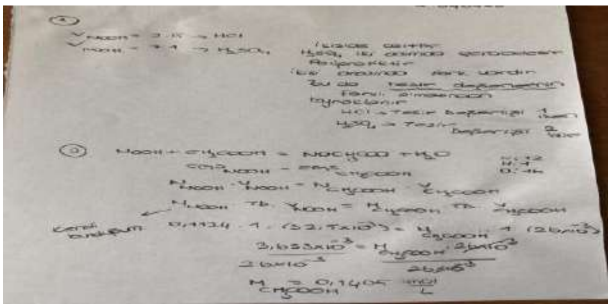

Figure 4: Example of Question

4. Research Steps

HCI analysis with standard NaOH and the results given for H_2SO_4 determination experiments were examined according to the determined criteria in *the first section*. The first of the behaviors expected from the students is saving the data. Students put the titrant they prepared into the burette in analytical chemistry quantitative analysis applications. They should note the first volume in the burette (V_1) and note the last volume after the experiment (V_2).

Writing the titration equation is an important behavior that requires the student to know the reaction of the analyte and titrant and to write an equation. The student will calculate the required information (concentration or volume) for the analyte with the equation.

The student will not achieve the required result without performing the behavior of converting the units. Therefore, he/she should know the units of the data to be used in the equation and make the necessary transformations according to the unit required.

The expected behavior is to write the potency value of the analyte/titrant. He/she needs to know the characteristics of the species he/she wants to find the concentration of when experimenting. Here, the student will write down the properties of the type for which he/she prepared the solution and whose concentration he/she knows.

Calculating the resulting behavior reveals whether the experiment has achieved its purpose. Writing the result unit behavior is controlling the units of information requested from the student with the unit he/she uses in equations and evaluating the result, that is, the answer.

Two questions were asked to reinforce the difference in the volumes spent in the experiments for HCI and H_2SO_4, and they were asked to solve and explain in *the second part*.

5. Data Analysis

The data of the research were collected with written answers including experimental calculations and question solutions. Evaluation criteria were developed by the research to evaluate these data. While determining the evaluation criteria, define the important or relevant features of the problem, creating and explain a strategy for the solution of the problem, and providing a possible strategy to solve the chemical problem were taken into consideration. A framework is drawn about the knowledge of the students about the concepts of chemical analysis, experiment, and chemistry when the evaluation is made according to these criteria (Shadle et. al., 2012).

The evaluation criteria determined by the researcher are as follows: Saving data, writing the titration equation, converting the units, writing the effect value, writing the titrant effect value, calculating the result, writing the resulting unit. The analytical chemistry laboratory sheets of universities, the opinions of the lecturers who have been teaching this course for a long time, and the gains of the reactions of the acids in the high school chemistry curriculum were taken into consideration while determining these behaviors (MoNE, 2018; KTU, 2019; Özyörük et.al., 1994). The results of the teacher candidates regarding the experiments were examined in the first part of the analysis of the data. The solution to the questions asked about the experiments was examined in the second part.

The data sheets obtained from the teacher candidates were examined according to saving the data, writing the titration equation, converting the units, number of H^+ ion analyte/equivalent of the analyte, number of OH^- ion titrant/equivalent of the analyte, calculating the result, writing the result units criteria. Coding was done according to true (T), partially true (PT), and false (F) categories during the examination. In coding, true (T) code is given when the result and unit are correct, partially true (PT) when the result is correct but the unit is incorrect, and false (F) code is given when the result and unit are incorrect. Problem solutions were coded as true (T), partially true (PT), and false (F) categories according to problem-solving and explanation criteria. Then, the analysis results were presented descriptively as frequency (f) and percentage (%) values. The data obtained from the study were analyzed independently by two researchers and the inter-rater reliability scores were calculated as 0.96. This value indicates high reliability (Miles & Huberman, 1994).

C. Result and Discussion

1. Result

a. Results related to the first section; NaOH, HCI, and H_2SO_4 Titrations

The first titration performed in the application process is the standardization of NaOH. Datasheets related to the results of this experiment were examined according to the determined criteria from the teacher candidates. Frequency and percentage values were calculated according to true (T), partially true (PT), and false (F) categories. The results of NaOH adjustment are given in Table 1.

Table 1. Conclusions for standardization of NaOH

Criteria	Categories	f	%
Saving data	T	6	46,2
	PT	2	15,4
	F	5	38,5
Writing the titration equation	T	12	92,3
	PT	1	7,7
	F	-	-
Conversion of units	T	4	30,8
	F	9	69,2
Number of H^+ ion analyte/ Equivalent of analyte	T	13	100,0
	F	-	-
Number of OH^- ion titrant/ Equivalent of analyte	T	13	100,0
	F	-	-
Calculation the result	T	3	23,1
	F	10	76,9
Writing the result units	T	7	53,8
	F	6	46,2

The second experiment of the application is HCI analysis with standard NaOH. H_2SO_4 determination is the last experiment with standard NaOH within the scope of neutralization titrations. Datasheets were examined as a result of this experiment. Percentage and frequency values of the categories are shown in Table 2 below.

Table 2. Conclusions for amount of HCI and H_2SO_4

Criteria	Categories	Amount of HCI		Amount of H_2SO_4	
		f	%	f	%
Saving data	T	5	38,5	10	76,9
	PT	1	7,7	3	23,1

	F	7	53,8	13	100,0
Writing the titration equation	T	10	76,9	-	-
	PT	1	7,7	-	-
	F	2	15,4	13	100,0
Conversion of units	T	1	7,7	-	-
	F	12	92,3	13	100,0
Number of H^+ ion analyte/	T	11	84,6	-	-
Equivalent of analyte	F	2	15,4	13	100,0
Number of OH^- ion titrant/	T	9	69,2	-	-
Equivalent of analyte	F	4	30,8	13	100,0
Calculation the result	T	1	7,7	-	-
	F	12	92,3	13	100,0
Writing the result units	T	10	76,9	-	-
	F	3	23,1	11	84,6

When the saving data criterion is examined, the rate of true recording in the standardization of NaOH titration, which is the first titration is 46.2% (f = 6), the rate of partially true recording is 15.4% (f = 2), and the rate of false recording is 38.5% (f = 5). Teacher candidates, who were determined to be partially true, were coded in this way either because they did not write the mass of the analyte to be used for titration or because they did not write the unit of the titrant volume they spent. Those who did not record any data related to analyte and titrant were coded as false. HCI determination titration which is the second titration, the true recording rate is (f = 5), 38.5%, the partially true recording rate is 7.7% (f = 1), and the false recording rate is 53.8% (f = 7). It is noteworthy that the rate of making mistakes increases in the second titration.

The candidates in false coding did not record any data whereas the candidate is partially true coding did not write the unit. When H_2SO_4 determination titration, which is the third titration, is examined, it is observed that the rate of true recording of the data is 76.9% (f = 10), and the rate of partially true recording is 23.1% (f = 3). It is noticed that there is an increase in the rate of true recording of data. Teacher candidates, who were coded partially true in this titration, wrote the volume of the spent titrant but did not write the unit. Examples of errors in writing units, true-false calculation the result, and errors in converting units are given below.

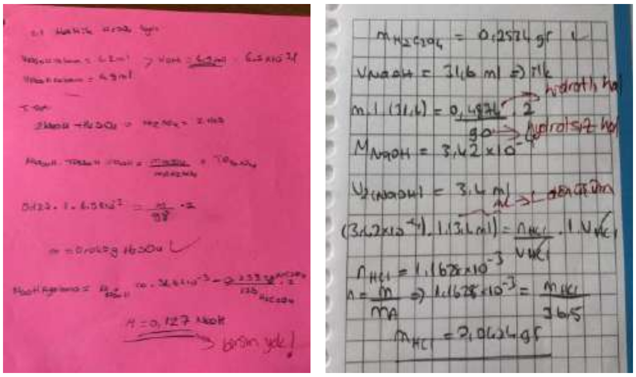

Figure 5: Example of an error in writing a unit

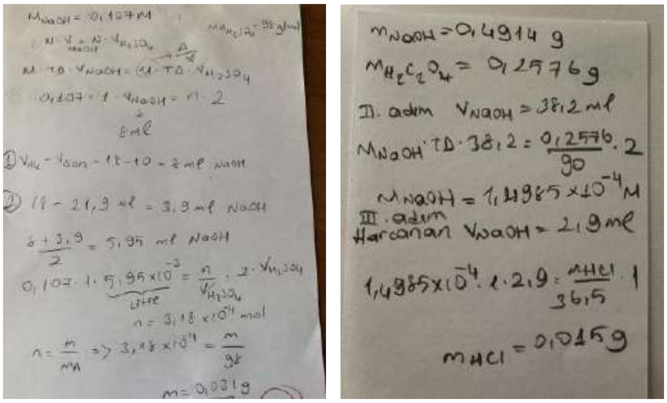

Figure 6: Example of true calculation the result

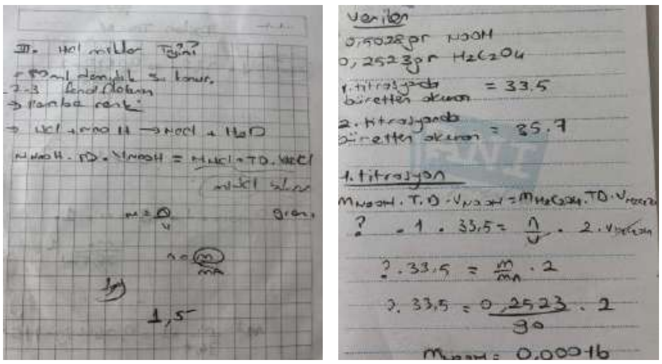

Figure 7: Example of false calculation the result

When the data of the criterion of writing the titration equation are examined, the first titration, which is the standardization of NaOH, it is noteworthy that the rate of true writing of the titration equation is 92.3% (f =12), the rate of partially true writing is 7.7% (f = 1), and there is no false writing rate. The candidate, who was coded partially true, went to the solution stage without writing an explanatory equation. In HCI determination titration which is the second titration, the rate of true writing of the titration equation is 76.9%, (f = 10), the partially true rate is 7.7% (f =1), and the false rate is 15.4% (f = 2). The increase in the rate of false writing in the second titration is noteworthy. Those who did not write any equation were coded as false whereas the candidate, who was coded partially true, went to the solution without writing an explanatory equation. It is noticed that all teacher candidates write the titration equation true 100% (f = 13), when H_2SO_4 determination titration, which is the third titration, is examined.

When the unit conversion criterion is examined, the rate of teacher candidates with the true conversion of the units in the first titration process is 30.8% (f = 4), while the rate of false conversion of units is 69.2% (f = 9). The majority of teacher candidates wrote in the equation without transforming the unit of the volume they read from the burette in these titration procedures. When the data in the second titration are examined, the true conversion of the units rate is 7.7% (f = 1), and the false conversion of the units rate is 92.3% (f = 12). It is noteworthy that the number of candidates who did not convert the units in this section is high. The true conversion of the units rate is 100% (f = 13), in the third titration.

It is noteworthy that all teacher candidates write the effect value of analyte and titrant correctly 100% (f = 13) when the criterion of writing the effect value is examined. The rate of true writing of the effective value of the analyte is 84.6% (f = 11), and the rate of false writing is 15.4% (f = 2), when the second titration is examined, the true writing rate is 69.2% (f = 9), and the false writing rate is 30.8% (f = 4) when the data on the effective value of titrant is examined in the second titration. The point that draws attention to false coding is that teacher candidates use the effect values in the previous titration here as well. The rate of true writing the effect value of analyte and titrant is 100% (f = 13), in the third titration, all teacher candidates wrote it correctly.

It is seen that the teacher candidates who found the result true by using the data obtained from the first titration are 23.1% (f = 3), and those who found the result false are 76.9% (f = 10) when the criterion of calculating the result is examined. It was found that the results of those who did not convert the units were false when the results of the first titration were examined. The rate of calculating the result truly is 7.7% (f = 1), whereas the rate of false calculating is 92.3% (f = 12), as a result of the second titration. The majority in the results of those with false unit conversion and effect value as a result of this titration is noteworthy. The rate of true calculating the result is 100% (f = 13), in the third titration.

When the criterion of writing the resulting unit is examined, the rate of true writing of the unit is 53.8% (f = 7), and the rate of false writing is 46.2% (f = 6), in the first titration. The rate of true writing of the unit is 76.9% (f = 10), and the rate of false writing is 23.1% (f = 3) in the second titration. The rate of true writing of the unit is 84.6% (f = 11), and the rate of false writing is 15.4% (f = 2) in the third titration. Teacher candidates either did not write the unit in the result they found or wrote the false unit, all of which were coded as wrong in the criterion of writing the resulting unit. The rate of writing the unit false decreased slightly more at the second titration and reached the lowest rate at the third titration whereas it was higher at the first titration.

b. Results related to problem-solving; HCI and H_2SO_4 Question/ Explanation

Neutralization titration experiments were performed in the analytical chemistry laboratory for three weeks. Teacher candidates were asked two questions in the fourth week of the semester based on the results obtained from these experiments. The questions are as follows:

Question 1: HCI and H_2SO_4 concentrations used in the two experiments is 0.1 M. Compare the NaOH volumes spent in the two neutralization titrations. Is there a difference between the two volumes? Explain why, if any.

Question 2: 32.5 mL of NaOH prepared last week is used to neutralize 26 mL of CH_3COOH solution. Calculate the CH_3COOH concentration accordingly. (Use the concentration calculated last week as the concentration of NaOH.) The answers to Questions 1 and 2 are given in Table 4 below.

Table 3. Conclusions for the amount of H_2SO_4

Problem	Categories	f	%
Question 1- problem solution	T	11	84,6
	F	2	15,4
Question 1- explanation	T	2	15,4
	PT	8	61,5
	F	3	23,1
Question 2- problem solution	T	13	100,0
	F	-	-
Writing the result units	T	9	69,2
	F	4	30,8

The rate of the true answer to Question 1 is 84.6% with 11 teacher candidates and the rate of the false answer is 15.4% with 2 teacher candidates as seen in Table 4. Teacher candidates who answered the question correctly reported that the volume spent for H_2SO_4 was more than that spent for HCI in their explanations. Teacher candidates who answered incorrectly stated that there was a difference between the two volumes and that less volume was spent for H_2SO_4.

The rate of true explanation is 15.4% (f = 2), the rate of partially true explanation is 61.5% (f = 10), and the rate of false explanation is 23.1% (f = 3) when we examine the explanation section of Question 1. Teacher candidates who made the true explanation stated that HCI was monoprotic and H_2SO_4 was diprotic, the amount of H^+ given to the environment was more, the volume spent for H_2SO_4 would be more. Teacher candidates who made a partially true explanation stated that this situation was caused by HCI's effect value being 1 and H_2SO_4's effect value being 2, but it could not be associated with the result. Teacher candidates who made a false explanation explained that HCI is a strong acid, H_2SO_4 is a weak acid, and therefore, less volume is spent in the weak one whereas more volume is spent in the strong one. Another explained that "*I spent more volume for H_2SO_4 because I missed the turning point and performed the experiment wrong*" (Figure 8).

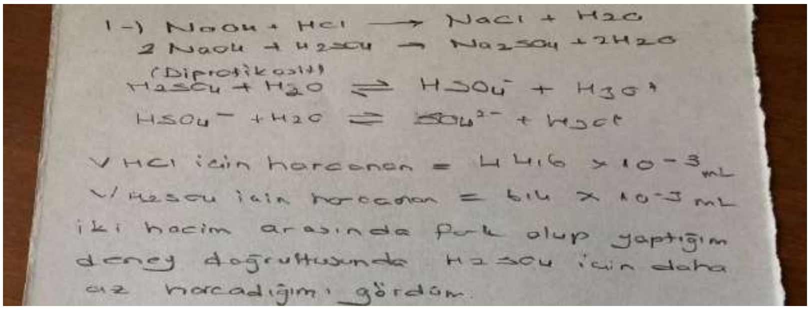

Figure 8. Example of false explanation.

It is seen that all teacher candidates solved the question correctly when the answers to Question 2 are examined. However, it is noteworthy that the rate of true writing is 69.2% (f = 9) and the rate of false writing or those who did not write anything is 30.8% (f = 4) when the criterion of writing the result unit is examined for the result.

2. Discussion

The ability level of chemistry teacher candidates to use the data obtained from the neutralization titration experiments in the calculation of the experiment result and the effect of the obtained information on solving the volumetric analysis problems were examined in this study. HCI analysis with standard NaOH and H_2SO_4 determination experiments were conducted for NaOH within the scope of the research. The data obtained from standardization of NaOH calculation, HCI determination, and H_2SO_4 determination data sheets were used to determine the problems experienced in calculating the experiment result.

The rate of true calculating the result in standardization of NaOH is 23.1% when the written responses given with the test results are examined. The rate of true calculating the result in HCI determination, which is the second titration, decreased to 7.7%. It is noteworthy that the rate of true calculating the H_2SO_4 amount, which is the third titration, is 100%. The rate of false writing the effect values of analyte and titrant is quite high in the first and second titration calculations. This is the reason why the results could not be found correctly. Teacher candidates wrote the effect value correctly and calculated the result correctly in the last titration.

The rate of the true solution of the first question is 84.6%, whereas the rate of the true solution of the second question is 100% when the answers to the two questions related to the subject are examined a few weeks after the experiments. It is noteworthy that there is no relationship between the effect value and the titrant volume to be spent in the explanations of the questions. This situation reveals that there is no trouble in solving the problem through the formula, but there are deficiencies in conceptual understanding and explanation level.

The data sheets obtained from the experiments conducted for neutralization titrations were evaluated according to the criteria of saving the data, writing the titration equation, converting the units, writing the analyze effect value, writing the titrant effect value, calculating the result, writing the resulting unit. It is noteworthy that there is an increase in the ability of teacher candidates to perform this behavior correctly when the three titration experiments conducted are examined according to the criteria of saving the data. It is noticed that all teacher candidates wrote the equation correctly at the last titration when the criterion of writing the titration equation is examined. It is seen that all teacher candidates did it right at the last titration while the rate of making mistakes at the first titration is quite high in the criterion of converting the units. The other criterion number of H^+/OH^- ion analyte/titrant monoprotic/diprotic acid was not initially distinguished and written incorrectly, then this was noticed and corrected. The last criterion is the increase in the rate of true calculating the result and true writing of the resulting unit.

Results similar to the errors in writing the titration equation, converting the units, writing the number of H^+/OH^- ion analyze/titrant, and calculating the result determined in the study are supported by the results in the literature. The most common errors encountered in solving volumetric analysis problems are that many of the students make mistakes while writing the molecular formula, or calculating the molecular mass of the compounds and write the mole rates incorrectly. On the other hand, most students have difficulty in writing formulas and equating equations.

The data obtained from the analysis performed in the titration experiment are either used to replace it in the formula or a proportion. It has been clarified by interviews that this data is the concentration of acid (Anamuah-Mensah, 1981). The calculations section, which forms part of the volumetric analysis, intimidates the students. Students find it difficult to develop the calculation part, or students are still in the concrete stages of cognitive development and have not yet learned formula-based operations such as titration calculations while they develop their experimental techniques by practicing (Johnstone, 1980). It is possible to direct students step by step from one level of thinking to another. In this way, the student is trained in logical thinking.

As a teacher, we should help the students develop a systematic approach when we encounter students who believe that relationships such as M1.V1=M2.V2 will be enough to solve the problem. Students should be asked to identify the solutions used in the titration. It is ensured that students establish a connection between the knowledge they have and the skill in this way. In addition, a diagram summarizing the steps to be followed by the students in titration calculations should be created. The steps in this diagram should be determined as determining the analyte-titrant, checking the units, writing the titration equation, using the stoichiometric ratios (explaining the effect value), calculating the required, checking the unit. It will be observed that students who follow the problem-solving network have increased confidence and skills in calculations (Waddling, 1983). Students have difficulty in making sense of chemical reactions.

Students are expected to be able to translate the expressions in the problem text into chemical and mathematical equations before solving the problem. However, there are difficulties in translating the words into mathematical equations (Hafs et. al., 2014). Students' working habits, reading skills, studying problems, and problems assigned as homework are also effective in learning volumetric analysis (Alam et. al., 2010). Information that is forgotten or confused after time passes through the experiments should be checked with the assignments given at certain time intervals and the permanence of the information should be ensured.

It should be ensured that the students prepare the solutions they will use in the experiments themselves to comprehend the purpose of chemistry experiments. For example, they better understand why the NaOH to be used in the neutralization experiment should be standardized, such that when the actual concentration of NaOH is lower in this way (McMills et. al., 2012). It cannot be said that the problem-solving steps used to solve a problem are the same or used for all problems. However, the solution to many problems proceeds as follows: understanding the problem, making plans for the solution of the problem, and evaluation steps. It was determined that the problem-solving approach supported by cooperative learning was more effective in solving quantitative problems of chemistry lessons (Bilgin, 2005).

Techniques should be used to allow students to divide the problem solution into steps, to prevent turning to the wrong steps, to achieve the right result, and to obtain reliable results (Tatar, 2015). While many students think chemistry is interesting (Cheung, 2009; Höft et.al., 2019), some students think that chemistry is quite boring, difficult, and challenging, while they think that some issues of chemistry are difficult to understand by nature, such as visualizing the structure of the atom and how chemical bonds occur (Rüschenpöhler & Markic, 2020). At the same time, young people state that chemistry is a difficult science and it is difficult to make a career in science (Mujtaba et. al., 2020). The solution to the problems will be easier, the likelihood of students making mistakes will be reduced, the ability to reach the right result will be gained, and problem-solving will be made fun with applications such as flow charts in solving quantitative analysis problems (Karaer, 2020).

Students should pay attention to conceptual understanding while studying and learning chemistry, and teachers should pay attention to conceptual understanding when teaching chemistry (Derman et. al., 2016). The biggest problem of today's teaching process is that students cannot add new information they learn in lessons or experiments to their knowledge base. Teachers should use different teaching techniques to ensure that students can perform this process. For example, it was determined that problem-solving techniques were more effective in teaching the subject of stoichiometry than traditional teaching (Sunday et. al., 2019). No one is unaware of the traditional laboratory understanding in which a detailed procedure is given for the experiment. The experiments generally aim to show the concepts learned in the lessons and to provide training on practical techniques in this laboratory understanding. However, students cannot have an idea about the actual design of the experiment (Wilson, 1987).

Students are quite aware that chemistry is related to various areas of our lives. These students are aware that problems will arise when they think that their knowledge of chemistry is insufficient to explain the relationship in these areas (Rüschenpöhler & Markic, 2020). More laboratory activity and practical studies should be carried out, and chemistry should also be associated with daily life to make chemistry more meaningful and interesting (Broman et. al., 2011). In addition, teaching materials related to the real world that will attract students' attention and arouse curiosity increase the success of students (Koçak Altundağ, 2018), improve scientific literacy (Rahmani et al., 2021).

D. Conclusion

The study examined the data obtained from the analytical chemistry neutralization titration experiments of chemistry teacher candidates, their level of use in calculating the test result, and the effect of the obtained information on solving volumetric analysis problems. It is very important to record the data, to write the titration reaction and equation, to calculate the result, and to convert the units in analytical chemistry laboratory experiments. It should be examined whether the difficulties experienced by teacher candidates in the determining criteria are also experienced in the general chemistry laboratory, physical chemistry laboratory, and organic chemistry laboratory experiments. Teacher candidates should be given practical information that they can use in all laboratories and these difficulties should be eliminated according to the results.

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