An analysis of students’ problem-solving ability on acid-base topic

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Abstract. This study aimed to analyze problem-solving ability of students on acid-base. Problem-solving ability of students was measured by three major aspects including understanding the problem, planning and applying the strategy, then checking the answer. The population of this study was all students in the public senior high school in Yogyakarta City. There were three schools with 150 students as the total of samples which were selected through the purposive sampling technique, focused on analyzing the high category of public senior high school. The level of the category was obtained using The Data of National Exam of Indonesian Students named PAMER 2016. The fact showed that the samples have already achieved the required level of thinking skills. This study was a sequential explanatory design; the quantitative data at the first phase were collected using problem-solving tests while the qualitative data were recorded through observation sheets during the learning process, and interviewing teachers and students after test were also performed to support the qualitative data. The results showed that problem-solving ability of the students is at the moderate category which means the students’ chemical problem-solving ability need to be upgraded as they are not yet in line with what is expected.

1. Introduction
Problem-solving ability is needed in the industrial revolution era from 2015 to 2020. The importance of problem-solving ability is also embedded in Indonesian curriculum, in the competence section of the knowledge mention that encourages students to understanding, applying, analyzing factual, conceptual, and procedural knowledge based on his curiosity about science, technology, art, culture and humanities with the insights of nationality, state and civilization on the causes of phenomena and events and applying procedural knowledge to specific areas of study in accordance with his talents and interests to solve problem [1]. The factual, conceptual, and procedural abilities mentioned in the curriculum are a type of knowledge that can distinguish problem-solving based on the strategies of each type of knowledge [2]. The role of conceptual knowledge and procedural knowledge in solving chemical problems is also explained by [3] that to be able to solve the chemical problem, students must have conceptual knowledge and procedural knowledge because with that knowledge can help students solve chemical problems such as the relationship between the chemicals they have learned with the condition of the environment, or the characteristics of chemicals they learn in the classroom can be applied through laboratory testing, and so forth. Conceptual knowledge includes conceptual
understanding and chemical theories, whereas procedural knowledge is an understanding of how to apply the concepts that have been learned in solving problems [3].

Problem solving is a process of overcoming difficulties that appear to interface with the attainment of a goal [4]. Problem-solving ability is the ability possessed by students in analyzing and solving problems or cases that ordinary or may be encountered in the implementation of a task [5]. It can be a procedure of making adjustment in spite of interferences. According to [6], problem solving ability is the basic skill of identifying problems and/or taking steps to resolve them, and when those problems situation occur they can adopt some useful strategies or steps for effective problem solving. The importance of problem-solving ability is also expressed by [7] whereas one of the indicators of intellectual behavior is the ability to solve the problem. This is in line with the argument of [8] that problem-solving ability is an indicator of success in learning that it involves the process of analyzing, interpreting, reasoning, predicting, evaluating, and reflecting. Problem-solving ability is often regarded as one of the complex high-level cognitive abilities. It is a very difficult intellectual task for secondary school chemistry students because of its complex intellectual processes [9]. The Complex problem solving consists two phases, the first phase is building a viable representation and the second phase is finding a way to reach certain goals [10]. These two phases describe that the point of problem solving step depends on how they start to take a way in solving the problems.

Steps in problem-solving are the good strategies that students can apply in solving chemical problems. According to [11] the problem-solving consists of five steps, including: (a) read what problems are given, (b) write down problems (write what problems are given), (c) write down what is being asked, (d) plan to solve the problems, and (e) solve the problems. The other steps that are basically associated with the task of problem solving advocated by [12], these are (a) identifying the problem, (b) defining and representing the problem, (c) exploring possible strategies, (d) acting on the strategies, and (e) looking back and evaluating the effect of one’s activities. Those steps are summarized by Polya that covering aspects: (a) understanding the problem, (b) planning the solution, (c) applying the strategy, and (d) checking the answers [13]. The steps in problem-solving that have been described can be applied in classroom learning by multiplying problem exercises tailored to aspects and indicators to be achieved to measure students' problem-solving abilities in chemicals. By applying problem exercises that identify problems and solve them, students are trained to find metacognition skills or high-order thinking skills [14].

Acid-base is one of chemistry subjects with comprehensive theories and mathematical problems. Acid base was chosen for the study because this material is a good foundation to success in hydrolysis and buffer materials. These materials are the area whereas secondary chemistry students have the greatest learning difficulties. As mentioned in the research by [15], acid base is one of chemistry topics from problem solving skills idea on a large amount of studies in science education research in recent decades. Some of studies describe the effective of problem solving skill or ability depend on Bloom’s learning theory. Thus, the focus of this study lies on the extent of the mastery of students in acid and base in terms of problem-solving ability aspects or indicators.

2. Research Method
2.1. Research Design
This study was a mixed-method sequential explanatory design which implied collecting and analyzing quantitative data and then qualitative data in two consecutive phases within one study. This research design depended on the type of data used.

2.2. The Research Samples
The population was a small population that was all students in the 11 public senior high schools in Yogyakarta City. The sample in this study focused on school that has already possessed high-level thinking criteria determined by high-level category of school based on The Data of National Exam of Indonesian Students through aplikation of PAMER 2016. It was chosen purposively, that is as many as three public Senior High Schools in Yogyakarta City which occupied the three highest ranking of eleven public schools in the same city. The reason for choosing these three high-grade schools was to
adjust the purpose of this study which will describe and prove how high the problem-solving ability that the students had, and to prove whether the school really has the skills - 21st century skills which is expected earlier. So that, this study was aimed to observe problem-solving ability of high school students in Yogyakarta city where the research sample should have high standard of thinking ability which was expected.

2.3. Data Collection

Test, observation and interview were the techniques of collecting data in this research. The test was conducted after the students received acid-base chemical topic. The problem-solving test instrument consisted 5 questions in the form of essay items which had been validated by 2 expert judgements and 1 practitioner and got alpha cronbach reliability 0.96. Furthermore, each of the items contained problem-solving indicators include identifying problems, selecting and developing strategies to solve problems, arranging problem-solving steps from beginning to end, checking out the results or answers, and drawing conclusions as mentioned in the Table 1.

| Aspects                      | No. | Indicators                                   |
|------------------------------|-----|----------------------------------------------|
| Understanding the problem    | 1.  | Identifying the problems                      |
| Planning and applying the    | 2.  | Selecting and developing strategies to solve  |
| strategy                     |     | problems                                      |
|                             | 3.  | Arranging problem-solving steps from          |
|                             |     | beginning to end                              |
| Checking the answer          | 4.  | Drawing conclusions                            |
|                             | 5.  | Checking out the results or answers           |

2.4. Data Analysis

The results of the students’ problem-solving ability were corrected with a score range of 1 – 5, whereas students get score 5 if their answer and completion step are correct; score 4 if the completion step is correct but the answer is incorrect; score 3 if the answer is correct but the completion step is incorrect or does not include the solving steps; score 2 if the answers and the solving steps are wrong but there is an attempt to answer the question; and score 1 if do not answer the questions. The quantitative data in this study were analyzed by using statistical descriptive calculations consisting average percentage, standard deviation, and frequency distributions. Moreover, the students’ problem-solving ability mastery levels were grouped into three categories as follow.

| Interval   | Category |
|------------|----------|
| > 75 %     | High     |
| 45 % - 75 %| Medium   |
| < 45 %     | Low      |

In addition, the observation and interview techniques were used to explained the quantitative results. The observation was applied during class and test, while the interview was done after test. The interview focused on the results of test so that the informants were the teacher and some of students who solve the problems incorrectly.

3. Results and Discussions

These findings of study focused to analyze problem-solving ability of students in acid and base chemistry subject. Using statistical descriptive calculations, the results of students' problem-solving ability was presented in the Table 3.
Table 3. The statistic descriptive data of problem-solving abilities

| Descriptions          | Values |
|-----------------------|--------|
| Total Responden       | 150    |
| mean score            | 65.2   |
| Standard deviation    | 12.69  |
| Highest Score         | 96     |
| Lowest Score          | 36     |
| Categories            | Moderate |

Based on Table 3, The most of students (65.2%) indicated have to the problem-solving ability in the moderate category/level, the highest score of students in solving chemistry problems was 96, and the lowest score was 36 whereas the difference between the higher score and the lowest score is far enough. Additionally, the percentage of students' chemical problem-solving abilities for each indicator can be seen in the Table 4.

Table 4. Percentage of problem-solving ability

| Question | Indicators                                      | Total | Percentage (%) |
|----------|-------------------------------------------------|-------|----------------|
| 1        | Identifying the problems                        | 567   | 3.78           |
| 2        | Selecting and developing strategies to solve problems | 534   | 3.56           |
| 3        | Arranging problem-solving steps from beginning to end | 505   | 3.37           |
| 4        | Drawing conclusions                             | 466   | 3.10           |
| 5        | Checking out the results or answers             | 374   | 2.49           |
|          | Total                                           | 2446  | 16.30          |
|          | Final Percentage                                | 65.2  |                |

Table 4 informs the indicator with the highest total score is an indicator: identifying the problems, which means that the students are superior in identifying the problem than other indicators. The indicator ‘identifying problem’ is the step of understanding the problem based on the Polya problem solving step. The indicator with the lowest total score is an indicator: re-examine the truth of the answer or checking out the results, which is the final step of solving Polya problem. These results reinforced the perception that basically students have the ability to understand the problem but not be careful in correcting back the truth of the answers written.

The next table illustrated the distribution of the frequency of the students who answered correctly based on the highest score to the lowest score obtained in solving the problem given. Through the following table it will be described about the frequency distribution of students in answering problem.
Table 5. Frequency distribution of student chemistry problem-solving

| Score | Question 1 | Question 2 | Question 3 | Question 4 | Question 5 | Total |
|-------|------------|------------|------------|------------|------------|-------|
| 5     | 54         | 43         | 30         | 59         | 18         | 204   |
|       | % 36        | 28.7       | 20         | 39.3       | 12         | 27.2  |
| 4     | 33         | 37         | 41         | 2          | 7          | 120   |
|       | % 22        | 24.7       | 27.3       | 1.3        | 4.7        | 16    |
| 3     | 41         | 35         | 42         | 11         | 16         | 145   |
|       | % 27.3      | 23.3       | 28         | 7.3        | 10.7       | 19.3  |
| 2     | 20         | 31         | 28         | 52         | 99         | 230   |
|       | % 13.3      | 20.7       | 18.7       | 34.7       | 66         | 30.7  |
| 1     | 2          | 4          | 9          | 26         | 10         | 51    |
|       | % 1.33      | 2.67       | 6.67       | 17.3       | 6.67       | 6.8   |
| Σ     | 150        | 150        | 150        | 150        | 150        | 150   |

Based on the Table 5, it could be seen that the distribution of students at most is still wrong in answering the problem and wrong in writing the problem-solving stage where as many as 30.7% of students got a score of 2. However, at least students have an effort in solving the problem proved by only 6.8% of those who did not answer the questions.

Figure 1. The distribution of students’ mastery in chemistry problem-solving

From the graph we also knew that most of students were not able to solve the problem correctly on the fifth question. Basically, the fifth question was intended to measure the students' chemical problem-solving abilities in terms of checking the truth of results or answers. When the students were less conscientious and/or wrote the wrong answer, they would not tend to re-examine the truth of the outcome or answer. This type of problem was the right type to measure the indicator. As for the question number 5 can be seen in this following statement.
Question 5:
Nadin gets the practicum assignment to make a strong acid solution in the laboratory. Nadin makes a HCl solution with concentrations of $10^{-9}$ M. She calculates the pH of the HCl solution is 9. Prove whether the pH calculation results are true or false and explain why!

Based on the (Figure 1) of the frequency distribution analysis of students who scored high to low, as many as 18 students who answered correctly on this matter with the score of 5; as many as 7 students who get a score of 4; as many as 16 students got score 3; and 99 students answered wrong; then 10 students did not answer the question. The outline of this results inform that most of students wrote the business and the problem-solving stage but the answers incorrect yet. They solved with calculation steps, but actually this type of question should be answered with a logical understanding of the concepts and/or explanations. The calculation will be obtained pH = 9, whereas pH = 9 is the range of pH base but actually HCl as we know is a strong acid. Creative problem-solving of students are aware of obstacles in the results of these calculations. Then, the determining factor should be the concentration. With a very dilute concentration of $10^{-9}$ M indicates that the solvent component in this case is water, has larger quantities than the HCl component. Thus, the pH of HCl is equal to the pH of water that is 7.

Most of students who were interviewed after answering this chemistry question believed the calculation pH = 9 was correct, and did not consider the true of concepts. Little of them caught there something wrong with the question, because it is HCl whereas an acid with pH lower than 7, but they got pH 9 from the calculation. They realized but did not explain on the answer sheet. They were aware of such an obstacle, but not many those who write the right reasons. They did not need to use any conceptual knowledge and understanding in order to solve mathematical problems in chemistry [3].

Figure 2. The relationship between conceptual knowledge and procedural knowledge by [3]
According to the teacher, students were not ready for the kind of question because they were exercised with mathematic problems only and still not mastery the concepts as well. The other teachers said that students had been given the type of questions but maybe they just realize without found the true of pH and too lazy to think the reasons. However, it was good enough because students had efforts to solved the problems with the steps even the answer was incorrect. Related to this case, [3] explained that to be able to solve the problem, student must have conceptual knowledge and procedural knowledge whereas conceptual knowledge includes conceptual understanding and chemical theories, while procedural knowledge is an understanding of how to apply the concepts that have been learned in solving problems. The question number 5 is the type of chemical problem that has relation with the condition of laboratory materials, so that students should applied the conceptual and procedural knowledge to solve it. To has conceptual knowledge and procedural knowledge in solving problem, students can apply the plot in the Figure 2.

In fact, most of students are weak in conceptual knowledge. They can successfully solve problems by using calculations or the algorithm questions rather than answering the argument questions based on the concepts involved. This fact is similar to [3] who informed that students with intellectual abilities in solving problems actually did not use it effectively. Although the results of the analysis were not in accordance with the hypothesis, but the results of the analysis with the category was basically been good enough. Most students were still wrong in answering the problem and wrong in writing the problem-solving stage since as many as 30.7% of students got a score of two. However, at least students have a business in solving the problem which was proved by only 6.8% of those who did not answer the questions. As for several factors that are likely to cause the results of the analysis to be so among them is the level of difficulty problems, analysis of students' answers, and the response of students to the test results. According to [16] causes students to make mistakes in answering the question that is related to cognitive activity, metacognitive ability, attitudes, and knowledge they have. The problem-solving process is one of carefully planned cognitive and skill strategies by individuals to achieve their goals [17]. Therefore, students who have the low achievement tend not to have clear plans and strategies in solving problems, and conversely students who have the high achievement tend to have a clear plans and strategies in solving the problem.

In addition, to the response and the ability of students in answering the question correctly, other factors that also affected the ability of solving the chemical problem of students were: a) problem-based learning model has not been applied in school even actually problem solving is one of learning purpose in the curricula, b) students were not well-trained with High Order Thinking Skills questions, and c) less preparation for taking the test. Several factors that affect the problem-solving skills of students include attitudes toward the teacher's lessons, enthusiasm, and teaching habits [18]. Teacher behavior carries direct and indirect influence on the problem-solving ability of students. Teachers are expected to apply learning methods that can develop this capability in depth and encourage students to be more enthusiastic about learning and having a good attitude and good concentration in learning.

4. Conclusion and Suggestion
Based on the students’ responses, it can be concluded that chemical problem-solving ability of the students is 65.2% indicating that they were at the moderate category which means that the students' chemical problem-solving ability need to be upgraded because they are not yet in line with what is expected. These results are influenced by several factors such as other problem-based learning models which have not been applied in the school, unfamiliarity of the students with the high order thinking questions, and less well prepared for taking the test.

Thus, it may be a good idea to initiate to do the same study with consideration of further research such as applying a modeling treatment or problem-solving strategy to find out or improve students' chemical problem-solving abilities.
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