Student certainty answering misconception question: study of Three-Tier Multiple-Choice Diagnostic Test in Acid-Base and Solubility Equilibrium

Ardiansah¹, M Masykuri¹ and S B Rahardjo²

¹Science Education Department, Universitas Sebelas Maret, Indonesia
²Chemistry Department, Universitas Sebelas Maret, Indonesia

E-mail: ardiansah@student.uns.ac.id

Abstract. Students’ concept comprehension in three-tier multiple-choice diagnostic test related to student confidence level. The confidence level related to certainty and student’s self-efficacy. The purpose of this research was to find out students’ certainty in misconception test. This research was quantitative-qualitative research method counting students’ confidence level. The research participants were 484 students that were studying acid-base and equilibrium solubility subject. Data was collected using three-tier multiple-choice (3TMC) with thirty questions and students’ questionnaire. The findings showed that #6 item gives the highest misconception percentage and high student confidence about the counting of ultra-dilute solution’s pH. Other findings were that 1) the student tendency chosen the misconception answer is to increase over item number, 2) student certainty decreased in terms of answering the 3TMC, and 3) student self-efficacy and achievement were related each other in the research. The findings suggest some implications and limitations for further research.

1. Introduction
The most students accepted chemistry become a difficult subject [1]. They also understand the subject at knowledge level and memorise the concept [2]. So that, they decide don’t learn chemistry and make a misconception [3]. The subject of chemistry like acid-base and solubility equilibrium is part of introductory chemistry. This subject becomes further subject in college. To enhance student comprehension, educators have tried the various method, media, and other pedagogical approaches. They conduct an instrument to address the cognitive and non-cognitive domain. For instance, achievement, motivation, ability, skill, and attitude. However, an effective aspect like self-efficacy, determined student success in learning chemistry, are not considered by the teacher as a factor affected low student achievement.

One of instrument that can measure both student comprehension of concept and confidence is a tiered-multiple-choice diagnostic test. Moreover, this instrument classifies into three categories that are two-, three-, and four-tier multiple-choice. However, the two-tier is not give student certainty and assume that student is certain with their own answer. So that, author use the three-tier. A three-tier multiple choice diagnostic test is currently developed to enhance the weakness of two-tier multiple-choice question. This instrument has several strengths those are (1) time efficiently, (2) determine the lack of knowledge or misconception [4], and (3) able to detect students’ confidence level. The 3TMC measures students’ misconception in several studies in chemistry [5–9]. With confidence level, the test also provides more information beyond the traditional one-tier multiple-choice and two-tier multiple-choice as the extra tiers of confidence ratings provide metacognitive information that helps to surface qualitatively
students' levels of certainty for their responses and, to a first approximation, how deep-seated these misconceptions are [10].

The certainty and confidence level are two terms can be related with self-efficacy. Bong [11,12] stated that self-efficacy acts as an active precursor of self-concept development and suggest that self-concept research separate out its multiple components and sub-processes and invest more effort toward making students less preoccupied with normative ability comparisons in school [12]. The first construct of self-efficacy comes from Bandura's Social Cognitive Theory [13,14]. Self-efficacy can be defined as a perception of students' own ability to do a certain task with their level of comprehension that in this case refer to concept comprehension. One of the misconceptions found in chemistry come from acid-base and solubility equilibrium subject.

The characteristic of acid-base and solubility equilibrium subject is difficult to understand. Many research conducts to examine and evaluate student understanding. The difficulties of this subject affect by its complexity. Johnstone stated that subject in chemistry consists of three levels that a) the macro and tangible: what can be seen, touched and smell; (b) the sub-micro: atoms, molecules, ions and structures; and (c) the representational: symbols, formulae, equations, molarity, mathematical manipulation and graphs [15,16]. Furthermore, the teacher also teaches in level symbolic only and focus on algorithmic comprehension [15] which require in the national examination at 12th grade. This case makes student only learn in rote learning than meaningful learning as scientist expected [17,18].

Regarding this issue, author interest to conduct a research about student achievement in conceptual level with this issue: (1) What is the student’s tendency in misconception? (2) What is the relationship between self-efficacy and achievement of the test?

2. Self-efficacy
Self-efficacy defined as the perception of a person about his/her ability to perform certain project with his level of proficiency or ability [19]. This indicator relevant to assess student certainty because if the student is not understood completely he/her will avoid the certain answer and choose the uncertain certainty level in the answer sheet. A student with good concept comprehension will make vigorous and persistent efforts and success in task [20,21]. To sum up, self-efficacy will increase with positive experience and decrease when met the negative experience[22].

Bandura [14] put forward four main sources of efficacy information: enactive mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states. Self-efficacy can be enhanced when individuals perceive themselves as capable of performing favourably. There were three dimensions of self-efficacy: (a) magnitude or level about the difficulty of the task, (b) generality which refer to mastery about task will be done by subject and its variation of activity, and (c) strength about the certainty of doing the task. With these three dimensions, this is important to determine students’ perception in performing a certain task. It can be measured by students’ self-efficacy after taking the chemistry subject. Also, student self-efficacy can become the predictor of student achievement [11].

Information from teacher sometimes cannot deliver by the student completely due to student own perception. The perception, how we view about something first, controlled student understanding in learning process if they cannot hold new conception. The tendency of student misconception is chosen the unscientific conception contrast with the accepted concept. Chemistry self-efficacy has been defined as a student's beliefs about his or her own capability to perform a chemistry task given[22,23]. These chemistry self-efficacy beliefs can be influenced by students' experiences in a course and could affect students' decisions to continue chosen the correct answer [22,24,25].

3. Research method
This is a mixed method which quantitative-qualitative method research. Quantitative data from student answer sheet in the 3TMC instrument. Qualitative method obtained from student answering tendency located in the third tier of the test. The purposes of the research were to: 1) Describe the tendency of
student misconception result in the research, 2) Relate student self-efficacy and achievement of the test, and 3) Result comparison between students in village and city.

3.1. Participants
The participant were students taken chemistry course in High School. The subject of research taught in end of the second semester of 11th grade. The students did this research as 484 students which divided into two parts. The first part in a regency with 124 students and the second parts in a city with 360 students participated. The gender or race are not counted in this research. Teachers taught this subject already qualified as a good educator and from chemistry education program. The teachers in this research already teach chemistry at least five years experiences.

3.2. Data collection tools
The data were collected using student questionnaire and the three-tier multiple-choice diagnostic test (3TMC). The questionnaire consists of ten question which includes of student lucky-guess response and the answering the question. The 3TMC includes of thirty questions about acid-base and solubility equilibrium. The question consists of three parts that answer part in first part, reason in second part, and the certainty in the third part. The first tier is correct-incorrect question while the second tier is traditional multiple-choice with four options and the third tier is a certainty with two choices that is certain and uncertain. The 3TMC developed in author previous thesis research with all question stated into valid using product moment correlation formula and have the reliability of Cronbach alpha .852 and .849 in each part. The result of validity using Aiken’s formulae [26] was .97 in average [27].

3.3. Data analysis
Data analysed using the quantitative method and describe as a descriptive method to obtain the result. The 3TMC count based on the student’s answer. Each answer interprets with standard measurement in misconception[4,28,29]. However, this research only focused on the third tier and result of misconception counted. The third tier was scored one for certain answer and zero points in the uncertain answer. After that, the author makes a recap from all of the participants in each item.

4. Result and discussion
Application of diagnostic theory to the misconception test suggest that student behaviour regarding the result of achievement test can be determined by his/her own confidence about his/her ability choosing the conception as his/her belief. Moreover, his/her belief about the concept can be related with other comprehensions, such as reading comprehension and mathematics comprehension. This is caused by chemistry also contain another level of comprehension that is sub-microscopic, macroscopic, and symbolic. It is important that one’s should have cultivated a positive self-efficacy developing his/her own unique conception. After that, author step is to address the confidence level of the student answering the misconception.

The self-efficacy in science education especially for chemistry generally assess using questionnaire [30]. They measured self-efficacy with interview and questionnaire triangulated between these two instruments. The result showed that higher self-efficacy determined lower probability to suffer setbacks academically. There were some studies stated that self-efficacy and science achievement related each other. Jensen in two paper stated this problem [31,32]. Student tent to have higher self-efficacy got the higher achievement in science subject that is chemistry, physics, and biology. Furthermore, student achievement also related each other with another science subject. A student with high self-efficacy sometimes attributed their successful. Also, student interest with certain subject affects student achievement. So that, they try to learn more than uninterested subject. However, Baumeister, Campbell, Krueger, and Vohs in Marsh & O’Mara [33–36] concluded that self-esteem— the global component of self-concept—has no effect on subsequent academic performance. Palmer [21] stated that the mastery of a subject can compensate by other skill. Cordova et al. [37] written that student with high
misconception and high confidence will success in conceptual change. These two results are shown before likely contrary each other so that we discuss the result of our recent research.

4.1. Student tendency chosen the misconception answer
The student, a participant in this test, sometimes have several alternative conceptions that still hold after teaching and learning process. They chose the question based on their own conception. Below showed the student misconception in every item.

![Misconception over Question Number](image)

**Figure 1.** Student misconception percentage over question number. The possible range of scores for misconception at each time point ranged from 4 to 66%.

The Figure 1 indicated that student misconception rate increase over question number make a positive slope. Generally, there was no significant gain or difference value of misconception over first and second part of the test. This result indicated that students have similar concept comprehension doesn’t depend on their school location. In some items, the first part is higher than second part and vice versa. In the first part, an average of misconception percentage is 21%. However, the second part shows that misconception average about 25%. Sia [38] stated that this part is attributed to students’ general unfamiliarity with being asked to justify their choice of responses to multiple-choice items in their normal course of study.

The highest misconception located in #6 question. The exceptional is question number #6 in both parts. The student assumes that ultra-dilute acid solution as a base. This conception contrary to Petrucci’s book [39] stated that water constant includes in the counting of pH so that the solution almost neutral. This statement means both solution concentration and a water concentration of hydrogen ion are counted in this case. Although this concept can include an exceptional case, the student also has to consider the concept. Petrucci mentioned the case of acid rain was related to this counting. Further, the water pH in students’ environment, West Kalimantan, also become focused on this question. Here showed the graphic of misconception average versus the certainty in two parts.
Figure 2. Comparison of students’ misconception and certainty in two parts of trials.

Based on the Figure 2, we obtained the tendency of student misconception tend to increase while students’ certainty decreases. The highest certainty or confidence level, question number 1 and 2 showed that students have a lower misconception. This means that student doesn’t hold specific misconception in this question. In the two graphical lines of students’ certainty, except item 10, we can see the first part is lower than the second part. This indicated student in the city has higher confidence level than in the village. With the confidence, the slope of the first trial generally lower than the second trial. However, the values are not too significant result for these two trials.

The students argue chosen the correct response in each item generally higher than a student that unconfident chosen their response. However, in first part question #11, #18, #29, and #30 include to the exceptional. These items showed that student chose not confident more than confident (Fig. 2). Students’ confidence answers these items regarding determine of strong base hydrolysis product with weak or strong acid, determine of behaviour of an acid buffer in base solution in human body, determine of molar solubility based on solubility constant in two different compounds, relate the addition of similar ion added into two different compounds that have same ions, is lower than other items.

The result trends might be attributed students’ anxiety and fear over the test. Palmer [21] stated that the response to their stress, fear, and anxiety are physiological and affective states of confidential information. The items which students chose confident answering the scientifically concept may be affected by the student keeping up-to-date with the subject and trying similar question before [40]. The concept comprehension also describes student they can determine the misconception and science accepted the answer. They usually also have a higher self-efficacy than another unsuccess student. Furthermore, the satisfied result caused by student curiosity to make a further comprehension.

4.2. Student self-efficacy and achievement relation in the research
This second research question we obtain the tendency of student self-efficacy represent by confidence level and achievement of this test. The achievement of the test counted by making an average of all score from all participant. Below we show the comparison with these two aspects.
The Figure 3 showed that two aspects slope tend to decrease over the item number. However, question #1, #6 and #8 indicated the different tendency of all items. The item #1 and #6 showed that student has a low result but have high confidence. The #8 item almost have the same percentage between students’ score and confidence level with 61% and 62% respectively. Furthermore, these anomalies cannot affect to the tendency of this comparison.

Consider to the previous result, we can conclude that student self-efficacy in this instrument decrease. There were some reasons might become the cause of this problem shown below:
1. The question is conceptual comprehension while the teacher focused on algorithmic comprehension. So that, the student cannot relate the algorithmic comprehension with conceptual whatever they understand the number counting.
2. The question given is too much. They tend to avoid the question and immediately want to finish the test.
3. Students still held their alternative conception. This problem forced the student to maintain their own conception till the last of teaching and learning process. It seems in a pattern of the misconception that increases over the question number. They consider their conception as a choice for their “correct answer”.
4. The student never did this type of question.

These reasons strengthen by student self-efficacy. Students with rote learning manner will have lower confidence than meaningful learning. In addition, the student tries to avoid the similar question that did not fit into their learning manner. A teacher with high experience and knowledge will contribute increasing students’ confidence and achievement only if this teacher can transfer the correct concept. Moreover, other students (classmates) can help one’s become higher self-efficacy like their vicarious confidence by teaching each other.

Students who have a strong belief that they can succeed in chemistry-related tasks and activities will be more likely to select such tasks and activities and work hard to complete them successfully [41]. Alternatively, students who do not believe that they can succeed in chemistry-related activities will avoid them if they can and will put forth the minimal effort if they cannot. When confronted with the typical challenges that science involves, they will be more likely to give up and to experience the stresses and anxieties that help ensure the erosion of their efforts [41]. Thus, self-efficacy is proposed to be an important factor influencing attitudes toward chemistry anxiety.
For the comparison of student correct answer, misconception, and confidence percentage, we give the result of our counting. Some items showed that misconception value more than all tier correct response. The question items are #6, #11, #18, #21, #25, #27, #29, and #30. However, no item that percentage of confidence lower than student achievement in all tier correct response.

Table 1. Comparison between all tier correct response, misconception, confidence level in both parts.

| No. | All tier | Misconception | Confidence | No. | All tier | Misconception | Confidence |
|-----|----------|---------------|------------|-----|----------|---------------|------------|
| 1   | 42       | 10            | 92         | 16  | 41       | 18            | 58         |
| 2   | 72       | 7             | 83         | 17  | 29       | 29            | 72         |
| 3   | 41       | 12            | 57         | 18  | 23       | 28            | 51         |
| 4   | 44       | 13            | 57         | 19  | 39       | 26            | 63         |
| 5   | 50       | 10            | 71         | 20  | 40       | 27            | 63         |
| 6   | 26       | 65            | 86         | 21  | 30       | 33            | 64         |
| 7   | 36       | 33            | 66         | 22  | 35       | 18            | 55         |
| 8   | 61       | 14            | 62         | 23  | 27       | 21            | 64         |
| 9   | 44       | 19            | 64         | 24  | 30       | 25            | 59         |
| 10  | 33       | 24            | 84         | 25  | 27       | 33            | 66         |
| 11  | 28       | 31            | 51         | 26  | 42       | 29            | 72         |
| 12  | 54       | 9             | 71         | 27  | 33       | 38            | 62         |
| 13  | 29       | 19            | 55         | 28  | 30       | 23            | 58         |
| 14  | 37       | 9             | 76         | 29  | 23       | 40            | 58         |
| 15  | 45       | 8             | 61         | 30  | 24       | 28            | 51         |

4.3. The result comparison of students’ characteristic in two parts
Based on the previous result, we can determine the comparison of students’ characteristic between a student in the village and in the city. In misconception result, there was no significant difference between two results. However, based on counting result, the percentage of misconception held by the student in village lower than in the city. It might be caused by the same tendency of student self-efficacy. The self-efficacy in village students were lower than a student in the city. It implicated to students’ percentage of misconception. A student that certain answering question probably has some possible result those are knowing the concept, false positive, false negative, and misconception. However, the students that don’t confident, they chose the uncertain choice which probability into another possible result such as lucky guess, lack of knowledge or don’t understand the concept.

5. Limitations and directions for future research
In this present study, we only measure students’ misconception in the domain of student self-efficacy or confidence level. We did not view student another concept comprehension, for instance, lack of knowledge, lucky-guess, positive- and negative false. The result may vary depending on student comprehension characteristic. However, this result becomes perquisite result about student conceptual. We suggest future study investigate other dimensions.

Furthermore, this study only focused on acid-base and solubility equilibrium chapter. This chapter only a part of chemistry taught in senior high school. Other chapters such as chemical bonding, thermochemistry, electrochemistry, equilibrium, and rate of reaction, have many misconception types. They might different result about student perception. This chapter only measures using the tiered question of misconception, we suggest further research using another instrument like questionnaire and interview to obtain a sharper result.

The research only conducted in West Kalimantan. The result might be varied in every province in Indonesia. Nevertheless, we conduct the stratified sampling to make sure our sample can measure all of
the population in the certain area. However, we cannot control student behaviour and student concept comprehension though taught by qualified teachers. Further bigger research might become a reference for the decision maker and government regarding this problem.

6. Conclusion

The student tendency answering misconception decrease over the question number. However, student self-efficacy showed from certainty level decreasing after a number of questions. This problem caused by some reasons which mentioned before. Furthermore, no significant difference between student misconception in city and village. In addition, we only see the confidence level obtained from student in city is higher than in village, which implicate to number of misconception.

Acknowledgement

References

[1] Ardiansah A 2016 Pros. Sem. Nas. Pendidik. Sains (SNPS) (Surakarta) p 49
[2] Cepni S, Tas E and Kose S 2006 Comput. Educ. 46 192–205
[3] Nakhlée M B 1992 J. Chem. Educ. 69 191–6
[4] Gurel D K, Eryılmaz A and Mcdermott L C 2015 J. Math. Sci. Technol. Educ. 11 989
[5] Cetin-Dindar A and Geban O 2016 J. Educ. Res. 671 1
[6] Kirbulut Z D and Geban O 2014 J. Math. Sci. Technol. Educ. 10 509
[7] Cetin-Dindar A and Geban O 2011 Proc. - Soc. Behav. Sci. 15 600
[8] Sonmez D Y 2015 Effect of Case-Based Learning Instruction On 11th-Grade Students’ Understanding Of Acids And Bases Concepts and Their Motivation to Learn Chemistry (Middle East Technical University)
[9] Milenkovic D D Hrin T N Segedinac M D and Horvat S 2016 J. Chem. Educ. 93 1514
[10] Hoe K Y and Subramaniam R 2016 Chem. Educ. Res. Pract. 17 263
[11] Lee W, Lee M J and Bong M 2014 Contemp. Educ. Psychol. 39 86
[12] Bong M and Skaalvik E M 2003 Educ. Psychol. Rev. 15 1
[13] Bandura A 1969 Handbook Social. Theory Res. p. 213
[14] Bandura A 1998 Self-efficacy Encycl. Hum. Behav. 4 1
[15] Johnstone A H 2000 Chem. Educ. Res. Pract. 1 9
[16] Taber K S 2013 Chem. Educ. Res. Pract. 14 156
[17] Gilbert J K, Treagust D, Davidowitz B, Chittleborough G, Representations M and Chemical I N 2009 Multiple Representations in Chemical Education 4
[18] Galloway K R and Bretz S L 2015 J. Chem. Educ. 92 2019
[19] Villafañe-Garcia S M 2015 Use of Assessments in College Chemistry Courses: Examining Students’ Prior Conceptual Knowledge, Chemistry Self-efficacy, and Attitude by Sachel M. Villafañe-Garcia A dissertation submitted in partial fulfillment of the requirements for the degree of (University of South Florida)
[20] Palmer D H 2002 Teachers Sci. Educ. 86 122
[21] Palmer D H 2006 Res. Sci. Educ. 36 337
[22] Villafañe S M, García C A and Lewis J E 2014 Chem. Educ. Res. Pr. 15 114
[23] Kurbanoğlu, N I and Akin A 2010 J. Teach. Educ. 35 48
[24] Villafañe S M, Bailey C P, Loertscher J, Minderhout V and Lewis J E 2011 Biochem. Mol. Biol. Educ. 39 102–9
[25] Xu X, Villafane S M and Lewis J E 2013 Chem. Educ. Res. Pr. 14 188
[26] Aiken L R 1985 Educ. Psychol. Meas. 45 131
[27] Ardiansah A, Masykuri M and Rahardjo S B 2017 Seminar Nasional Pendidikan Sains (SNPS) pp 104
[28] Damanhuri M I M, Treagust D F, Won M and Chandrasegaran A L 2016 Int. J. Environ. Sci. Educ. 11 9
[29] Eryılmaz A 2010 J. Educ. Res. 53
[30] Dalgety J, Coll R K and Jones A 2003 J. Res. Sci. Teach. 40 649
[31] Jansen M, Scherer R and Schroeders U 2015 Contemp. Educ. Psychol. 41 13
[32] Jansen M, Schroeders U and Ludtke O 2014 Learn. Individ. Differ. 30 11
[33] Marsh H W and O’Mara A 2008 Personal. Soc. Psychol. Bull. 34 542
[34] Marsh H W, Byrne B M and Shavelson R J 1988 J. Educ. Psychol. 80 366
[35] Marsh H W and Hau K-T 2004 J. Educ. Psychol. 96 56
[36] Marsh H W, Kong C-K and Hau K-T 2001 J. Educ. Psychol. 93 543
[37] Cordova J R, Sinatra G M, Jones S H, Taasoobshirazi G and Lombardi D 2014 Contemp. Educ. Psychol. 39 164–74
[38] Sia D T, Treagust D F and Chandrasegaran A L 2012 Int. J. Sci. Math. Educ. 10 1325
[39] Petrucci R H, Herring F G, Madura J D and Bissonnette C 2017 General chemistry : principles and modern applications (Ontario: Pearson Canada Inc.)
[40] Sia D T 2010 Science and Mathematics Education Centre Development and Application of a Diagnostic Instrument to Evaluate Secondary School Students’ Conceptions of Electrolysis Ding Teng Sia (Curtin University of Technology)
[41] Britner S L and Pajares F 2006 J. Res. Sci. Teach. 43 485