The Diagnosis of Misconception on The Concept of Acid-Base Theory in Prospective Teacher Students Used a Three-Tier Test

Rusmini\textsuperscript{1,2}, Suyono\textsuperscript{2}, Budi Jatmiko\textsuperscript{3}, Bertha Yonata\textsuperscript{2}

1. Doctoral Program Universitas Negeri Surabaya
2. Department of Chemistry Education, Universitas Negeri Surabaya
3. Department of Physic Education, Universitas Negeri Surabaya

drusmini@unesa.ac.id

Abstract. Several phenomena of misconception have been discovered worldwide. In misconception, students strongly believe in the truth of the answers chosen of the questions given but the answers are wrong. This study aims to identify misconceptions that occur in first year students on the concept of acid-base theory. These students are pre service student in chemistry education. As prospective teachers, these students should be free from misconceptions so that they will not bring misconception to their own students one day. This study used a three tier diagnostic test to diagnose misconception from 125 students (1\textsuperscript{st} and 2\textsuperscript{nd} year) as data resources. The students have been given paper and pencil test consist of 15 questions. Each question consists of three levels, namely the choice of concept answers at the first level. The second level is the reason for the answer to the first level question. The third part is the level of confidence in the answers and reasons. Data analyzed to determine the percentage of misconceptions. The results showed that the first year students experienced misconceptions type 1, 2 and 3 in the low category. There were no students who guessed the answers.

Keywords: acid base theory, misconceptions type 1, misconceptions type 2, misconception type 3, three tier diagnostic tests

1. Introduction

The current learning concerned on how students learn well and get a true understanding of concepts. Students understand concepts since they have known the world. They learn from natural phenomena before get on formal education. When they learn by observing natural phenomena which obtained partially or no understanding accordance with scientific concepts while its truth is recognized. Their understanding can be improved when taught the correct concepts. But the deeply embedded understanding which cannot be repaired for a moment and return to their original understanding. This original understanding is not accordance with scientific concepts. They believe these false concept is true, namely as misconception.

Lately, many misconceptions occur in the world of education [1-6]. Students strongly believe in the truth of the answers to the questions given but the answers given are wrong. Misconceptions arise because of students’ misunderstanding of a concept. This happens because students have a wrong
initial understanding and that is difficult to change. It can also be caused by incomplete thinking, human error, stages of development that have not yet reached the level of abstraction and so on. Another cause is due to the ability of students to distinguish specific attributes from a concept and be more focused on general attributes. The number of relevant and irrelevant special and general attributes contributes to the occurrence of misconceptions. Students' environmental backgrounds such as culture, language, friends become one of the triggers for misconception. Another source of misconceptions that is very dangerous is the learning resources used by students containing misconceptions. Wrong material writing in the book will unwittingly trigger this misconception. Teachers who experience misconceptions will teach the same thing to their students so this will continue to spread and increasingly endanger the world of education [7-10].

Identification of misconceptions has long been developed. It through open interviews [11,12]; pictures [13,14]; concept maps [15] and multiple choice tests [16]. An open interview is able to provide an in-depth investigation and can provide a more detailed description of results about the cognitive structure of students. But it takes a long time to interview a large number of research subjects [17]. Open tests also give students ample opportunity to write answers in their own sentences. But this will require a large amount of time to analyze the answers and assess the results of student answers [17]). Multiple choice tests are one of the most common ways to identify misconceptions. This is because multiple choice tests can be given to a number of students at the same time. Easy to manage, easy to analyze even though it is not able to provide further investigation on students' answers. In traditional multiple-choice tests researchers cannot distinguish the correct answers to correct scientific conceptions and wrong reasons [17]. Multiple choice tests that are used to identify include tests in the form of two tiered tests [18-20]. The two tier tests have two levels of questions, the first level of content questions and the second level of reason questions. This type of test provides an opportunity to detect and calculate the proportion of wrong answers with the correct reasons (false negative) and the correct answers with the wrong reasons (false positive). However, a two-level test cannot distinguish lack of knowledge, misconceptions, as well as from scientific conceptions, false positives or false negatives [21]. For this reason, researchers developed a three-tiered test to identify misconceptions [4, 21-24]. Three-tiered tests are the development of a two-level test by adding a level of confidence to level three. With a three-tier misconception test can be assessed for errors that are believed by students. Errors can appear in the content section or in the reasons section.

Given the importance of misconception to be known, it is necessary to identify misconceptions in 1st semester students. This is important because it is to prevent the emergence of protracted misconceptions. Identification in the early stages of lectures is expected to prevent misconceptions in the next semester. Identification of misconceptions is done through basic chemistry courses on the basic theory of acid and base. This material was chosen because based on the results of other studies show that misconceptions occur in acid-base material [1, 4, 25]. This research used diagnostic misconception instrument using three tier tests as many other researchers have used. Three tier test diagnostic instruments are predicted to be able to identify students' conceptual understanding and misconceptions more accurately than one tier or two tier diagnostic tests [21, 26]. Three tier tests can be considered as a more valid and reliable instrument for the assessment of achievement, conceptual understanding and or misconception [21, 26, 27]. This study aims to identify the misconceptions of 1st semester students on the basic theory of acid base sub-material. The results of the study are expected to be a reference and source of information for researchers and lecturers to overcome and follow up on students' misconceptions on the concepts of acids and bases.

2. Method

In this research, there were 30 students from 1st year and 95 students from 2nd year as data resources. The students have been given paper and pencil test consist of 15 questions. Data collection techniques used a three-tier diagnostic test instrument consisting of 15 items. Each question consists of three levels, namely the choice of concept answers at the first level. The second level is the reason for the answer to the first level question. And the third part is the level of confidence in the answers and
reasons. Data on diagnostic test results are expressed as a percentage of knowing concepts, not knowing concept and type 1 misconceptions, type 2 misconceptions and type 3 misconceptions. The validity of the questions has been tested through feasibility tests by chemists and education experts. Diagnostic tests used are questions for the concept of acid-base theory. The problem contains 13 indicators which are elaborated in 15 questions. The list of problem indicators is in Table 1.

Table 1. Indicator diagnostic test questions

| NO | INDICATOR                                           | Number of problem |
|----|-----------------------------------------------------|-------------------|
| 1  | Defining acids according to Arrhenius               | 3, 1              |
| 2  | Defining bases according to Arrhenius               | 2                 |
| 3  | Choose examples of bases according to Arrhenius     | 8                 |
| 4  | Choosing acid samples according to Arrhenius        | 5                 |
| 5  | Explain the properties of the Bronsted Lowry theory | 6, 4              |
| 6  | Determine the nature of acid and base reversible reactions according to Bronsted Lowry | 7 |
| 7  | Determine acid base properties according to Bronsted Lowry | 10 |
| 8  | Determine alkaline properties according to Bronsted Lowry | 15 |
| 9  | Defining acids and bases according to G.N. Lewis    | 11                |
| 10 | Choose an example of Lewis acid                     | 12                |
| 11 | Select examples of Lewis bases                       | 13                |
| 12 | Defining acids according to G.N. Lewis              | 14                |
| 13 | Defining bases according to G.N. Lewis              | 9                 |

This research is a quantitative and qualitative descriptive study. The results of the misconception test were analyzed quantitatively. The results of the study were analyzed using qualitative descriptive methods. Based on the answers given by the students, a pair of answers from tier 1, 2 and 3 is made to determine the category of knowing concepts, not knowing concepts, guessing or misconceptions of type 1, misconceptions of type 2 and misconceptions of type 3. More clearly stated in table 2.

Table 2. Categories of answer pairs from 3 tiers

| Tier 1 | Tier 2 | Tier 3 | Kategori          |
|--------|--------|--------|-------------------|
| True   | True   | Sure   | knowing concepts  |
| False  | True   | Sure   | misconceptions of type 1 |
| True   | False  | Sure   | misconceptions of type 2 |
| False  | False  | Sure   | misconceptions of type 3 |
| True   | True   | Not sure | guessing          |
| True   | False  | Not sure | not knowing concepts |
| False  | True   | Not sure | not knowing concepts |
| False  | False  | Not sure | not knowing concepts |

After getting a category for each answer, calculate the percentage of each answer with the formula

\[ P = \frac{S}{N} \times 100\% \]

Note:

P = Percentage of students who experience knowing the concept, not knowing the concept, guessing, or misconception

S = Number of students who experienced the concept, not knowing the concept, guess, or misconception.

N = Number of students taking the test.
Related to misconceptions, based on test results then grouped into the category of misconceptions as in table 3.

Table 3. Misconception Categories

| Percentage of Category | Category |
|------------------------|----------|
| 0-30%                  | Low      |
| 31-60%                 | Medium   |
| 61-100%                | High     |

3. Results and Discussion

Previous research has focused more on developing three-tier diagnostic tests. While in this study the research data obtained were analyzed to determine the categories of misconceptions type 1, 2 and 3. Based on the results of the three-tier diagnostic tests conducted, the results obtained as in table 4.

Table 4. Results of three tier diagnostic tests

| Question number | KC (%) | NKC (%) | MC1 (%) | MC2 (%) | MC3 (%) | Total (MC) (%) |
|-----------------|--------|---------|---------|---------|---------|---------------|
| 1               | 21.88  | 6.25    | 15.63   | 40.63   | 15.63   | 71.88         |
| 2               | 0.00   | 9.38    | 62.50   | 0.00    | 28.13   | 90.63         |
| 3               | 21.88  | 9.38    | 6.25    | 59.38   | 3.13    | 68.75         |
| 4               | 3.13   | 25.00   | 6.25    | 3.13    | 62.50   | 71.88         |
| 5               | 56.25  | 6.25    | 12.50   | 15.63   | 9.38    | 37.50         |
| 6               | 31.25  | 6.25    | 18.75   | 6.25    | 37.50   | 62.50         |
| 7               | 3.13   | 12.50   | 9.38    | 50.00   | 25.00   | 84.38         |
| 8               | 84.38  | 3.13    | 9.38    | 3.13    | 0.00    | 12.50         |
| 9               | 0.00   | 15.63   | 3.13    | 21.88   | 59.38   | 84.38         |
| 10              | 37.50  | 15.63   | 21.88   | 3.13    | 21.88   | 46.88         |
| 11              | 28.13  | 9.38    | 0.00    | 62.50   | 0.00    | 62.50         |
| 12              | 21.88  | 15.63   | 56.25   | 3.13    | 3.13    | 62.50         |
| 13              | 15.63  | 15.63   | 59.38   | 6.25    | 3.13    | 68.75         |
| 14              | 65.63  | 12.50   | 12.50   | 9.38    | 0.00    | 21.88         |
| 15              | 3.13   | 12.50   | 3.13    | 46.88   | 34.38   | 84.38         |

average: 26.25 low, 11.67 low, 19.79 low, 22.08 low, 20.21 low, 62.08 low

Note: KC: knowing concepts; NKC: Not knowing concepts; MC1: misconceptions type 1; MC2: misconceptions type 2; total MC: the sum of misconception 1, 2 & 3

Know the concepts known from the correct student answers in content and reasons accompanied by confidence in the answers. If students know a concept correctly, the storage of information in long-term memory is in accordance with theories about the concept. Correct understanding of one concept will affect understanding of another concept. And vice versa with those who do not know the concept. Do not know the concept indicated by the wrong answer to the concept content, reason or both and answer not sure at the tier of belief. Meanwhile misconceptions that occur include misconceptions type 1, type 2 and type 3. All three types are still stated as misconceptions. Of the three types of misconceptions, the largest data occurred in type 2 misconceptions (MC2), namely 22.08% where students answered correctly on content and wrong on giving reasons. This shows students are easier to answer than giving reasons or giving reasons for answers. This shows students are not strong in understanding concepts. When students’ concept of understanding is very strong, students will be able
to explain a concept well despite the reversal of facts. When they find various forms of questions, students will be able to answer correctly. The weakness of students in giving reasons for an answer provides opportunities to improve students’ abilities in higher-order thinking skills.

Students have obtained acid-base material when high school in XIth grade student. Students most likely have forgotten the concepts of acid-base or student retention of weak acid-base concepts. Weak retention (memory) of students of a concept causes students more quickly forget the material or concepts that have been studied previously. The low understanding of student concepts is related to the complexity and abstractness of the concepts being tested [21]. Students have difficulty abstracting concepts correctly. It might also be because most students have forgotten the material previously studied or student retention is weak against certain concepts. Weak retention (memory) of students on the material that has been learned causes students to quickly forget the material and formulas they have memorized [28]. Weak student answers can also be a result of interference. According to interference theory, it is assumed that information that has been stored in long-term memory still exists in the memory warehouse, but that the memory traces are mixed up, disturbing each other. It could be that newly received information interferes with the process of remembering old information, but it can also happen otherwise [29].

The results of this study are similar to other studies that use three-tier diagnostic tests in diagnosing misconceptions by distinguishing students’ level of understanding from one another. There are students who know the answers and reasons for the answers, but there are also students who are able to answer but are unable to provide reasons for answers and vice versa. Meanwhile students are sure of the answers they have chosen. Thus this result is expected to be a material for further evaluation of the level of semester 1 students’ understanding of acid-base theory. This three-tier diagnostic test is easily applied to all students to detect misconceptions so that prevention can be done because these students are prospective teachers who will someday they will convey to their students. So hopefully the spread of misconceptions can be interrupted.

4. Conclusion

Based on this study it can be concluded that based on diagnostic test results it is known that 1st and 2nd year students experience type 1, type 2 and type 3 misconceptions respectively in the low category. The implication of this research are expected for further evaluation about the level of 1st and 2nd year students’ understanding of the acid base theory to prospective teacher students so that it is expected that the spread of misconceptions can be interrupted. This research has a limitation that only uses three tier diagnostic tests to analyze the evidence of misconceptions. While other studies have used four-tier diagnostic and five-tier diagnostic tests, although three-tier tests have been able to diagnose misconceptions in students. Further research that can be done from this research is to treat students who have been identified as having misconceptions. In addition, there are still great opportunities to use four-tier or five-tier tests related to the understanding of symbolic representatives in chemistry.

5. References

[1] Widarti, H. R., Permanasari, A., & Mulyani, S 2017 Undergraduate Students’ Misconception on Acid Base and Argentometric Titrations: A Challenge to Implement Multiple Representation Learning Model with Cognitive Dissonance Strategy, International Journal of Education, 9/2: 105-112

[2] Berg, Kevin De 2012 A Study of First Year Chemistry Students Understanding of Solution Concentration at The Tertiary Level. The Royal Society of Chemistry: Chemistry Education Research and Practice. Chem. Educ. Res. Pract. 13: 8-16.

[3] Barke, H D 2013 Structure of Matter – Diagnosis of Misconceptions and Challenge. Novo Sarajevo, Bosnia & Herzegovina: Bulletin of The Chemists and Technologists of Bosnia and Herzegovina. Http://Www.Pmf.Unsa.Ba/Hemija/Glasnik/.
[4] Mubarokah, F.D. & Sri Mulyani, Indriyanti N. Y. 2018 Identifying Students’ Misconceptions of Acid-Base Concepts Using a Three-Tier Diagnostic Test: A Case of Indonesia and Thailand. *Journal of Turkish Science Education, 15*(Special Issue), 51-58

[5] Kanawati, I., Fratiwi, N. J., Danawan, A., Suyana, I., Samsudin, A., & Suhendi, E. 2019 Analyzing Students’ Misconceptions About Newton’s Laws Through Four-Tier Newtonian Test (Fnt). *Journal of Turkish Science Education, 16/1*: 110-122

[6] Prodjosantoso, A. K., Hertina, A. M., & Irwanto 2019 The Misconception Diagnosis on Ionic and Covalent Bonds Concepts with Three Tier Diagnostic Test. *International Journal of Instruction 12/1*: 1477-1488

[7] Ausubel, D P 2000 *The Acquisition and Retention of Knowledge: A Cognitive View.* (Dordrecht: Kluwer Academic Publishers)

[8] Dahar, R. Wilis 2011 *Teori-Teori Belajar Dan Pembelajaran.* (Jakarta: Erlangga.)

[9] Lemma, A 2013 A Diagnostic Assessment of Eighth Grade and Their Teachers’ Misconceptions About Basic Chemical Concepts, *African Journal of Chemical Education (AJCE), 3/1*: 39-59

[10] Chiu, M H 2005 A National Survey of Students’ Conceptions in Chemistry in Taiwan, *Chemical Education International. 6/1*: 1-8

[11] Chen, S M 2009 Shadows: Young Taiwanese Children’s Views and Understanding. *International Journal of Science Education 31/1*: 59–79.

[12] Palmer, D 2001 Students’ Alternative Conceptions and Scientifically Acceptable Conceptions About Gravity.” *International Journal of Science Education 23/7*: 691–706

[13] Kose S 2008 Diagnosing Student Misconceptions: Using Drawings as A Research Method *World Applied Science Journal, 3/2*: 283-293

[14] Ehrlén, K 2009 Drawings as Representations of Children's Conceptions. *International Journal of Science Education 31/1*: 41–57

[15] Kaya, O N 2008 A Student-Centred Approach: Assessing The Changes in Prospective Science Teachers’ Conceptual Understanding by Concept Mapping in A General Chemistry Laboratory. *Research in Science Education, 38/1*: 91–110.

[16] Korur, F 2015 Exploring Seventh-Grade Students’ and Pre-Service Science Teachers’ Misconceptions in Astronomical Concepts. *Eurasia Journal of Mathematics, Science & Technology Education 11/5*: 1041–1060.

[17] Kaltakci-Gurel, Eryılmaz, & Mcdermott 2017 Development and Application of a Four-Tier Test to Assess Pre-Service Physics Teachers’ Misconceptions About Geometrical Optics, *Research in Science & Technological Education, 35/2*: 238-260

[18] Chen, C, H. S. Lin, & M. L. Lin 2002 Developing A Two-Tier Diagnostic Instrument to Assess High School Students’ Understanding- The Formation of Images by Plane Mirror. *Proceedings of The National. Science Council Part D 12/3*: 106–121

[19] Tan, K.C.D., Goh, N.K., Chia, L.S., & Treagust, D.F. 2002 Development and Application of a Two-Tier Multiple- Choice Diagnostic Instrument to Assess High School Students’ Understanding of Inorganic Chemistry Qualitative Analysis.” *Journal of Research in Science Teaching 39/4*: 283–301
[20] Odom, A. L., & L. H. Barrow 1995 Development and Application of a Two-Tier Diagnostic Test Measuring College Biology Students’ Understanding of Diffusion and Osmosis After a Course of Instruction. *Journal of Research in Science Teaching, 32*: 45–61.

[21] Taslidere, Erdal 2016 Development and Use of a Three-Tier Diagnostic Test to Assess High School Students’ Misconceptions About the Photoelectric Effect, *Research in Science & Technological Education. 34/2*: 164-186

[22] Caleon, I. & Subramaniam, R 2010 Development and Application of a Three Tier Diagnostic Test to Assess Secondary Students’ Understanding of Waves. *International Journal of Science Education, 32/7*: 939–961

[23] Silung, S.N.W., Kusaeri S., & Zulaikah, S 2016 Diagnosis Miskonsepsi Siswa Sma Di Kota Malang Pada Konsep Suhu Dan Kalor Menggunakan Three Tier Test, *Jurnal Pendidikan Fisika Dan Teknologi, 2/3*:95-105

[24] Hasyim W, Suwono, H, & Susilo H 2018 Three-Tier Test to Identify Students’ Misconception of Human Reproduction System, *Jurnal Pendidikan Sains* 6/2:48–54

[25] Barke, H D. Harsch, G, & Schmid 2012 *Essential of Chemical Education*. (Berlin: Springer – Verlag Heidelberg)

[26] Arslan, H O, Cigdemoglu, C, and Moseley 2012 A Three Tier Diagnostic Test to Assess Pre-Service Teachers’ Misconceptions About Global Warming, Greenhouse Effect, Ozone Layer Depletion, and Acid Rain, *International Journal of Science Education, 34/11*: 1667-1686

[27] Sen, S. & Yilmaz A 2017 The Development of a Three-Tier Chemical Bonding Concept Test, *Journal of Turkish Science Education, 14/1*: 110-126

[28] Slavin, Robert E 2011 *Psikologi Pendidikan Teori dan Praktek Edisi Kesembilan Jilid 1* (Jakarta: PT. Indeks)

[29] Moreno, Roxana 2010 *Educational Psychology*. (USA: John Wiley and Sons)

**Acknowledgments**

Acknowledgments to chemistry education students 2018 and biology education study program 2019A students who have been respondents in taking research data.