Development of Three Tier Multiple Choice Diagnostic Test to Assess Students’ Misconception of Chemical Equilibrium

W Siswaningsih*, Nahadi and R Widasmara
Departement of Chemistry Education, Universitas Pendidikan Indonesia.

*Corresponding Author’s email: wiwi2450@gmail.com

Abstract. The aim of study was to develop the three-tier multiple choice diagnostic test that was conform with criteria of content validity and reliability to identification students’ misconception about chemical equilibrium. The method of this study was development and validation methods. Fourteen items were developed in this study. Based on the value of content validity ratio (CVR), all items were valid. The value of reliability of items were developed is 0.759, it means that items were acceptable. The respondents of this study were 5 validators who are lecturers from Department of Chemistry Education and 35 senior high school students’ who was learned subject chemical equilibrium. Based on analysis of students’ answer were based on a determination key could be found students’ misconceptions that on dynamic equilibrium, concentration of reactant and product are same as common misconception in the student (57.1%).

1. Introduction
Chemistry is one of the lessons that students learn in school. Chemistry become a difficult subject to understand some students because they contain abstract such as moles, molecules and particles atoms and electrons [1]. Chemistry consist of three levels of representation, they are: (1) the representation of the macroscopic levels that describe the bulk properties of the phenomenon and is seen in the daily experience of students, (2) the representation of the submicroscopic levels that provide explanation on the particular levels, and (3) the symbolic representations that involves the use of chemical symbols, formulas, equations, diagrams, models, and animations [2]. The ability to master the three-level representation chemical that the reason why chemistry so difficult to learn by students.

The result of Ozmen et al [3], Sendur et al [4] and Cheung et al [5]’s research’s, tell us about the misconceptions of chemistry often occur in chemical equilibrium. That the misconception arises because students cannot link the properties of matter at the level of representation used to illustrate and explain the chemical phenomenon. In several studies on education, it is stated that misconception is one of the problems that students face in learning. Misconceptions that happens to students can comes from inappropriate textbooks, digest error some information and students’ interaction with surrounding environment [6]. Students can be stated experiencing misconceptions if students’ concept different from their teacher or scientist concerned at certain subject [7]. Before we overcome the problem about students’ misconception, first we must to assess misconceptions that occur on students. To identify misconceptions that known a test called diagnostic test [8,9]. Diagnostic test can be done by interview or written test [10].

Some research about diagnostic test does already exist on two tier type like Tuysuz’s research [11] about development of two-tier diagnostic test. But, in two tier diagnostic test, that have a problem because sometimes student can predict the answer without knowing where the answer come from.
Therefore, to overcomes about these problems, the result of Hasan’s research [11] tell us about Certainty of Respond Index (CRI) that can use on third tier of a diagnostic test. So, now we often hear about three tier diagnostic test that the third tier is certainty of response index [12]. The certainty of responds index can tell us about how much that the students certain about their answer and we can decide the student have misconceptions or do not know the concept at all. Three tier diagnostic test can identify of student’s misconceptions more specific than the two-tier diagnostic test [13]. Therefore, with this three-tier diagnostic test we can choose the most efficient feedback for students.

2. Method

The method used in this study is development and validation method [14]. Development of an activity increases one thing to perform certain steps and validation is the process of an investigation carried out in describing the items [15]. This study carried out through four stages, there are: (1) the developments stage items, (2) the validation phase, (3) the stage of determining determination key, and (4) the test phase of development application. The first stage carried by adapting and modifying the development stages with reference to the proposed Treagust stages [16]. These stages namely, (1) the determination of the purpose and scope of the test, (2) the collecting data of predict students misconceptions, and (3) development design test of three tier multiple choice diagnostic test on chemical equilibrium concepts.

3. Results and Discussion

3.1 Grain development problem

Development of Three Tier items have three tier that the first tier is based on text books and research journals regarding the material concept of the chemical equilibrium with consisted of three possible answer, a correct answer and three distractor. The second tier is consisted of six possible reasons that based on one true concept and some misconceptions from research about chemical equilibrium [16,17]. The last is third tier that based on certainty of response index with two possible choice, sure or not sure. The first design of this test has 15 items questions of chemical equilibrium concepts.

3.2 Quality test

The test design that have 15 items, then tested for validity and reliability. A total of 14 items are declared valid, then tested to 35 high school students of XI class that has been studying in chemical equilibrium. Based on material calculation with SPSS that the value of Cronbach alpha is 0.727 which is in the range $0.7 \leq a < 0.8$. The range is included in the category of “acceptable” so all 14 items that used again on application test. The 14 items that used in application test that recalculated the value of Cronbach alpha with SPSS. Based on material calculation again, the value of Cronbach alpha is 0.759 which is in the range $0.7 \leq a < 0.8$. The range is included in the category of “acceptable” [18].

3.3 Students misconception on dynamic equilibrium

Items that have been declared valid and reliable where than applied to 35 high school students of XI class that has been studying in chemical equilibrium on application test.
Table 1. Students’ Answer at Dynamic Equilibrium Concept Reagent Number One

| No | Question                                                                 | Students’ Answer | Qty. | %  |
|----|---------------------------------------------------------------------------|------------------|------|----|
| 1  | Note the following reaction illustration of chemical equilibrium.          |                  |      |    |
|    | $A + B \rightleftharpoons C$                                              |                  |      |    |
|    | That reaction called at equilibrium state if ….                          |                  |      |    |
|    | A. Concentration of reactant (A and B) and concentration of product (C)  |                  |      |    |
|    | are change                                                                |                  |      |    |
|    | B. Concentration of reactant (A and B) < concentration of product (C)    |                  |      |    |
|    | C. Concentration of reactant (A and B) dan concentration of product (C)  |                  |      |    |
|    | constant                                                                  |                  |      |    |
|    | The reason, because at equilibrium state:                                |                  |      |    |
|    | i. The rate of forward reaction is greater than the reverse reaction rate  |                  |      |    |
|    | ii. Reaction rate towards the product is not same with reaction rate      |                  |      |    |
|    |    towards the reactant                                                   |                  |      |    |
|    | iii. Reaction does not occur                                              |                  |      |    |
|    | iv. Reaction rate towards the product is same with reaction rate          |                  |      |    |
|    |    towards the reactant                                                   |                  |      |    |
|    | v. Forward reaction goes to completed before the reverse reaction starts   |                  |      |    |
|    | vi. Concentration of reactant dan concentration of product are            |                  |      |    |
|    |    same                                                                    |                  |      |    |
|    | Are you sure?                                                             |                  |      |    |
|    | Sure                                                                      |                  |      |    |
|    | Not sure                                                                  |                  |      |    |
|    | A.i Sure                                                                  |                  |      |    |
|    | A.ii Not Sure                                                             |                  |      |    |
|    | A.iii Sure                                                                |                  |      |    |
|    | A.iv Sure                                                                 |                  |      |    |
|    | B.i Sure                                                                  |                  |      |    |
|    | B.ii Not Sure                                                             |                  |      |    |
|    | B.iii Not Sure                                                            |                  |      |    |
|    | B.iv Not Sure                                                             |                  | 3    | 8.6|
|    | B.v Not Sure                                                              |                  |      |    |
|    | B.vi Not Sure                                                             |                  |      |    |
|    | C.i Not Sure                                                              |                  |      |    |
|    | C.ii Not Sure                                                             |                  |      |    |
|    | C.iii Not Sure                                                            |                  | 1    | 2.9|
|    | C.iv Not Sure                                                             |                  | 8    | 22.8|
|    | C.v Not Sure                                                              |                  |      |    |
|    | C.vi Not Sure                                                             |                  | 20   | 57.1|

Base on table 1, a response pattern C(iii) with a total percentage of 2.9% stated that at the equilibrium state, concentration of reactant and product are constant because at equilibrium state no reaction occurs. The pattern C(vi) with a total percentage of 57.1% stated that at the equilibrium state, concentration of
reactant and product are constant because at equilibrium state concentration of reactant and product are same [19]. Percentage misconceptions response pattern that is equal to 60%, to do not understand the concept 17.20% and to understand the concept as much as 22.80%. From these data, we can see three categories of students’ understanding shown in Figure 1.

![Figure 1. Percentage of Students on Dynamic Equilibrium Concept](image)

**Figure 1.** Percentage of Students on Dynamic Equilibrium Concept

Base on figure 1, students misconceptions identified on the labels on the material concept with the concept of dynamic equilibrium percentage of 60%, homogeneous equilibrium percentage of 63%, heterogeneous equilibrium percentage of 37.30%, equilibrium constant (\(K_c\)) percentage of 51.40%, correlation between temperature and equilibrium constant (\(K_c\)) percentage of 31.50%, correlation between quosien (\(Q\)) and equilibrium constant (\(K_c\)) percentage of 37.2%, equilibrium constant based on gas pressure (\(K_p\)) percentage of 25.80%, Principle of Le Chatelier on dynamic equilibrium percentage of 28.75%, Change of concentration to affect the equilibrium state percentage of 23%, Change of temperature to affect the equilibrium state percentage of 37.20%, Change of volume to affect the equilibrium state percentage of 41%, Change of pressure to affect the equilibrium state percentage of 40%, and adding catalyst on equilibrium state percentage of 40.20%. The most misconception experienced by students is at dynamic equilibrium concept with stated that at the equilibrium state, concentration of reactant and product are constant because at equilibrium state concentration of reactant and product are same [20,21].

4. **Conclusion**

Three Tier Multiple Choice Diagnostic Test developed with stem on first tier with three possible answers, the second tier in the form of reasons with six possible answer and third tier that have two possible answers. The result of validations stage that the test developed have 14 items declared valid by five validators. Total of 14 items tested reliability and the alphas’ value about 0.759. Based on the test content and reliability, as many as 14 items have been categorized as good and acceptable. The most misconception experienced by students is at dynamic equilibrium concept with stated that at the equilibrium state, concentration of reactant and product are constant because at equilibrium state concentration of reactant and product are same.

5. **References**

[1] Abbas M L H 2016 Pengembangan Instrumen Three Tier Diagnostic Test Miskonsepsi Suhu dan Kalor Ed-Humanistics 1 2 83-92

[2] Adams W K and Wieman C E 2011 Development and validation of instruments to measure learning of expert-like thinking International Journal of Science Education 33 9 1289-1312

[3] Barke, H D, et al 2009 Misconception in Chemistry Verlag Berlin Heidelberg: Springer

[4] Bayrak B K. 2013 Using Two Tier Test to Identify Primary Students’ Conceptual Understanding an Alternative Conceptual in Acid Base Mevlana International Journal of Education (MIJE) 3 2 19-26
[5] Chandrasegaran A L, Treagust D F, and Mocerino M 2007 The Development of a two tier multiple choice diagnostic instrument for evaluating secondary school students’ ability to describe and explain chemical reaction using multiple levels representation *Chemistry Education Research and Practice* **8** 3 293-307

[6] Cheung D, Ma H J, and Yang J 2009 Teachers’ misconceptions About The Effects Of Addition Of More Reactants Or Products On Chemical Equilibrium *International Journal of Science and Mathematics Education* **7** 6 1111-1133

[7] Firman, H 2018 *Evaluasi Pembelajaran Kimia* Bandung: Jurusan Pendidikan Kimia Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

[8] Gliem J H and Gliem R R 2003 Cronbach’s Alpha Reliability Coefficient for Likert-Type Scale *Midwest Research Practice Conference in Adult, Continuing, and Community Education Calculating, Interpreting, and Reporting* **87**

[9] Nahadi, Firman H, and Ulum M 2018 Development and validation of reasoning-based multiple choice test for measuring the mastery of chemistry. *Journal of Engineering Science and Technology* **13** 6 1476-1488

[10] Nahadi, Siswaningsih W, and Muhtar H K 2017 An investigation into students’ misconception on electrolyte and non-electrolytes solutions with two tier diagnostic test based pictorial *Journal of Advanced Science Letters* **23** 11 10555-10558

[11] Hasan S, Bagayoko D, and Kelley E L 1999 Misconceptions and the certainty of response index (CRI) *Physics education* **34** 5 294-299

[12] Lawshe, C H 1975 A Quantitative Aproach to Content Validity *Personnel Physichology* **28** 563-575

[13] Nahadi, Firman H, and Farina J 2015 Effect of Feedback in Formative Assessment in the Student Learning Activities on Chemical Course to the Formation of Habit of Minds *Jurnal Pendidikan IPA Indonesia* **4** 1 36-42

[14] Ozmen H 2007 Determination of Student’s Alternative Conceptions about Chemical Equilibrium: A Review of Research and The Case of Turkey *Chemistry Education Research and Practice* **225**

[15] Sendur G, et al 2011 How Can Secondary School Students Perceive Chemical Equilibrium? *E-Journal of New World Science Academy* **6** 3 1512-1531

[16] Suhendi H Y, Kaniawati I and Maknun J 2014 Peningkatan Pemahaman Konsep dan Profil Miskonsepsi Siswa Berdasarkan Hasil Diagnosis Menggunakan Pembelajaran ECIRR Berbantuan Simulasi Virtual dengan Instrumen Three-Tier Test *Mathematics and Sciences Forum*

[17] Taber, K S 2009 Challenging Misconceptions in the Chemistry Classroom: Resources to Support Teachers *Educacio Quimica EduQ* **4** 2 13-20

[18] Treagust, D F 2007 Development and Use of Diagnostic Test to Evaluate Students’ Misconceptions in Science *International Journal of Science Education* **10** 2 159-169

[19] Tuysuz, C 2009 Development of two-tier diagnostic instrument and assess students’ understanding in chemistry *Scientific Research and Essay* **4** 626

[20] Nahadi, Firman H, Kurniadi A 2018 Development and Validation of Multiple Representation-Based Virtual Test to Assess Students’ Decision-Making Competence of Buffers *Journal of Education and Learning (EduLearn)* 44-51

[21] Nahadi, Anwar S, and Kharisma D 2017 Investigating formative assessment strategy to chemistry habits of mind (Chom) of buffer solution concept in learning chemistry habits of mind (CHOM) of buffer solution concept in learning chemistry *The Turkish Online Journal Of Educational Technology* 276-285