Student’s profile of misconception in chemical equilibrium

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Abstract. The chemical equilibrium concept is a basic and complex concept in chemistry. The aim of this study was to analysis the student’s misconception of chemical equilibrium. Topic of chemical equilibrium concept consist of three subtopics there are dynamic equilibrium and equilibrium constants, Le Chatelier principles, and interpreting the experimental results in equilibrium state. The participant consisted of six students, two students from high, two from the medium, and two from the low ranked school category. The instrument used to identify student’s profile misconception was the Computerized Two Tier Multiple Choice (CTTMC). There is subtopic on the concept of chemical equilibrium that most likely causes misconception that is, interpreting the experimental results in equilibrium state.

1. Introduction
The chemical equilibrium is a basic concept for students’ understanding of other chemical topics. Mastery of the concept of equilibrium is closely related to other chemical concepts [1]–[3]. Chemical equilibrium materials include defined concepts, abstract concepts, mathematical calculations, and graphs. In studying chemical equilibrium, students are required to master several other related concepts such as concepts of concentration, stoichiometry, gas, and mole.

Misconceptions are defined as perceptions of phenomena occurring in the real world that are inconsistent with scientific explanations of phenomena [4]. The different concept from the generally agreed scientific understanding of a term is called misconception. When students connect new information to a cognitive structure that already has an inappropriate knowledge, this misconception interferes with subsequent learning. Thus, weak understanding or misconception of the concept will occur because the new information cannot be connected appropriately to their cognitive structure [5]. Banerjee developed a written test to diagnose the misconceptions of chemistry students and teachers at school. The analysis shows misconceptions about equilibrium levels, the prediction of equilibrium conditions and the application of the principle of equilibrium to daily life [6].

The methods that have been used to identify students’ understanding of concepts including concept mapping [7], multiple choice diagnostic test [8], and interview [9]. This study used computerized two tier multiple choice (CTTMC) instrument which is modification of TTMC to identification student’s profile of misconception in chemical equilibrium. This methodology has been used in chemistry, for example in inorganic chemistry [10], solution chemistry concept [11], chemical reaction [12], chemical equilibrium [6], [13], [14].

The two tier multiple choice (TTMC) diagnostic test, the first level of each multiple choice consists of content questions that usually have two to four options. The second level of each item containing a set is usually four possible reasons for the answer given in the first section. The reason consists of the correct answers, along with the conception and / or misunderstanding of the students identified[15]. Two tier multiple choice tests can make providing conceptual understanding of students easy for the
teacher on account of determining the reasons of alternative concepts of students, obtaining the ratio of frequency in students and the teacher’s being aware of these alternative concepts and their reasons[13].

The development of methods to investigate students' understanding of individual concepts directed by an analysis of understanding concepts[9]. In addition to understanding students 'ideas that are scientifically wrong, the use of two-tier tests allows teachers to exploring students' reasoning behind these ideas. Two tier tests also facilitate the assessment of alternative conceptions of larger student samples in a more efficient [2], [16]. But there is no study that describes the students' profile of misconceptions, especially on the concept of chemical equilibrium. Therefore, in this article the researcher will describe the students' profile misconception on the concept of chemical equilibrium.

2. Research Method

The method used in this research was descriptive method. The participant in this study were students in three high school category, high, medium and low ranked schools in the city of Surakarta. The subjects consisted of six students, two students from high, two from the medium, and two from the low ranked school category. Data on student conceptions were collected by tests. The instrument used to identify student’s profile misconception is the computerized two tier multiple choice (CTTMC), developed by modifying the procedure of TTMC [8]. The CTTMC was developed in three subtopics of chemical equilibrium consisting fifteen question number for identifying student’s misconception. Three subtopics of chemical equilibrium: Dynamic equilibrium and equilibrium constants, Le Chatelier principles, interpreting the experimental results in equilibrium state [1], [6]. Question number 1-5 is about dynamic equilibrium and equilibrium constants, question number 6-10 is about Le Chatelier principles, and question number 11-15 is about interpreting the experimental results in equilibrium state.

Students responses were marked in three levels of undersstanding, understand, misconception and don’t understand. Based on research [17] and by adapting [18], the application of the Graded Response Model on CTTMC instrument scoring is as follows:

| First Tier | Second Tier | Score | Level of Understanding |
|------------|-------------|-------|------------------------|
| True       | True        | 3     | Understand (U)         |
| True       | False       | 2     | Misconception (M)      |
| False      | True        | 1     | Misconception (M)      |
| False / No | False / No  | 0     | Don't understand (DU)  |
| Answer     | Answer      |       |                        |

3. Result and Discussion

| Question Number | Student 1 | Student 2 | Student 3 | Student 4 | Student 5 | Student 6 |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1               | 1         | 0         | 1         | 1         | 1         | 0         |
| 2               | 3         | 3         | 3         | 3         | 3         | 3         |
| 3               | 3         | 3         | 1         | 0         | 2         | 3         |
| 4               | 2         | 2         | 2         | 2         | 0         | 2         |
| 5               | 3         | 0         | 3         | 3         | 0         | 3         |
| 6               | 3         | 3         | 3         | 3         | 3         | 3         |
| 7               | 3         | 3         | 3         | 3         | 3         | 3         |
| 8               | 3         | 3         | 3         | 3         | 3         | 3         |
The CTTMC score in table 4 then translates into a level of understanding as in table 1. From Table can be seen question number 1,4,12,13,14,15 most often cause misconceptions. For more details, the profile of student’s misconception of six students from three categories of schools will be described in the table below.

Table 3. Misconception of student 1

| Question number | Sub subtopic                                           | Student Misconception                                                                 |
|-----------------|--------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1               | Finding the composition of the substance in a state of equilibrium | Students assume that the substances contained in a state of equilibrium is the product only |
| 4               | Finding the relationship of pressure, concentration, and temperature to the ideal gas system | Students assume that in the ideal state gas system, the concentration is directly proportional to the pressure and temperature |

Table 3 shows that Student 1 from high ranked school was misconception in question number 1 and 4, on the first subtopic, dynamic equilibrium and equilibrium constants. From question number 1, Student 1 don’t understand the state of equilibrium, there are product and reactant in certain amount. From question number 4, Student 1 don’t understand in the ideal state gas system, the concentration is directly proportional to the pressure and inversely proportional to the temperature.

Table 4. Misconception of student 2

| Question number | Sub subtopic                                           | Student Misconception                                                                 |
|-----------------|--------------------------------------------------------|---------------------------------------------------------------------------------------|
| 4               | Finding the relationship of pressure, concentration, and temperature to the ideal gas system | Students assume that in the ideal state gas system, the concentration is directly proportional to the pressure and temperature |
| 13              | Analyzing the composition of the product in a state of equilibrium when it has been known the number of moles of the reacting agent | Students can’t compare the composition of the substance concentration at the time of equilibrium |
| 14              | Predicting the concentrations of reactants to be added if known Kc | Student knows that concentration of all products divided by the concentration of the gas-phase reactant is removed by the coefficient number, but can’t predict the concentrations of reactants to be added. |

Table 4 shows that student 2 from high ranked school just misconception in question number 4,13 and 14, on the first and third topic, about dynamic equilibrium and equilibrium constants and interpreting the experimental results in equilibrium state.
Table 5. Misconception of student 3

| Question number | Sub subtopic                                                                 | Student Misconception                                                                                                                                 |
|-----------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1               | Finding the composition of the substance in a state of equilibrium          | Students assume that in a state of equilibrium the concentration of the substances in the product and the reactants is the same.                      |
| 3               | Formulating an equilibrium constant based on pressure                       | Student knows that on a heterogeneous equilibrium the solids pressure is assumed to be fixed, but can’t formulating an equilibrium constant based on pressure |
| 4               | Finding the relationship of pressure, concentration, and temperature to the ideal gas system | Student assume that in the ideal state gas system, the concentration is directly proportional to the pressure and temperature                           |
| 14              | Predicting the concentrations of reactants to be added if known Kc         | Student knows that he concentration of all products divided by the concentration of the gas-phase reactant is removed by the coefficient number, but can’t predict the concentrations of reactants to be added if known Kc |
| 15              | Predicting the concentration of each substance in a state of equilibrium | Student can’t predict the concentration of each substance in a state of equilibrium, but knows that the number of moles of the product and reactant is directly proportional to the reaction coefficient |

Table 5 shows that student 3 from medium ranked school was misconception in question number 1, 3, 4, 14 and 15, on the first and third subtopic, about dynamic equilibrium and equilibrium constants and interpreting the experimental results in equilibrium state.

Table 6. Misconception of student 4

| Question number | Sub subtopic                                                                 | Student Misconception                                                                                                                                 |
|-----------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1               | Finding the composition of the substance in a state of equilibrium          | Student assume only the reactants are in a state of equilibrium                                                                                       |
| 4               | Finding the relationship of pressure, concentration, and temperature to the ideal gas system | Student assume that in the ideal state gas system, the concentration is equal to the amount of pressure                                                   |
| 12              | Finding the concentration of substances in a state of equilibrium if known concentrations of certain substances | Student knows that the number of moles of the reactant and product substances is directly proportional to the reaction coefficient, but can’t find the concentration of substances in a state of equilibrium |
| 13              | Analyzing the composition of the product in a state of equilibrium when it has been known the number of moles of the reacting agent | Students can’t compare the composition of the substance concentration at the time of equilibrium                                                       |
| Question number | Sub topic | Student Misconception |
|----------------|-----------|-----------------------|
| 14             | Predicting the concentrations of reactants to be added if known $K_c$ | Student knows that concentration of all products divided by the concentration of the gas-phase reactant is removed by the coefficient number, but can’t predict the concentrations of reactants to be added. |
| 15             | Predicting the concentration of each substance in a state of equilibrium | Student can’t predict the concentration of each substance in a state of equilibrium, but know that the number of moles of the decomposed and formed substances is directly proportional to the reaction coefficient. |

Table 6 shows that student 4 from medium ranked school just misconception in question number 1, 4, 12, 13, 14 and 15, on the first and third topic, dynamic equilibrium and equilibrium constants and interpreting the experimental results in equilibrium state.

**Table 7. Misconception of student 5**

| Question number | Sub topic | Student Misconception |
|----------------|-----------|-----------------------|
| 1              | Finding the composition of the substance in a state of equilibrium | Student assume that all substances are present in the state of equilibrium at the same amount. |
| 3              | Reconstruct the concept of homogeneous and heterogeneous equilibrium pressure concepts | Student assume that at a heterogeneous equilibrium the gas pressure is considered fixed. |
| 13             | Analyzing the composition of the product in a state of equilibrium when it has been known the number of moles of the reacting agent | Student can’t compare the composition of the substance concentration at the time of equilibrium. |
| 14             | Predict the concentrations of reactants to be added if known $K_c$ | Student knows that the concentration of all products divided by the concentration of the gas-phase reactant is removed by the coefficient number, but can’t predict the concentrations of reactants to be added if $K_c$ was known. |
| 15             | Predict the concentration of each substance in a state of equilibrium | Student can’t predict the concentration of each substance in a state of equilibrium, but student knows that the number of moles of the reactant and product substances is directly proportional to the reaction coefficient. |

Table 7 shows that student 5 from low ranked school have misconception in question number 1, 3, 13, 14 and 15, on the first and third topic, dynamic equilibrium and equilibrium constants and interpreting the experimental results in equilibrium state.
Table 8. Misconception of student 6

| Question number | Sub topic                                                                 | Student Misconception                                                                                                                                 |
|-----------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4               | Finding the relationship of pressure, concentration, and temperature to the ideal gas system | Student assume that in the ideal state gas system, the concentration is directly proportional to the pressure and temperature.                        |
| 7               | Predicting the direction of equilibrium shift                             | Student knows if the pressure is minimized equilibrium will shift in the direction of the number of moles or the coefficient higher, but can’t predict which substance increases. |
| 12              | Finding the concentration of substances in a state of equilibrium if known concentrations of certain substances | Student knows that the number of moles of the decomposed and formed substances is directly proportional to the reaction coefficient, but can’t find the concentration of substances in a state of equilibrium |
| 13              | Constructing the stoichiometric concepts of equilibrium reactions        | Student can analyzing the composition of the product in a state of equilibrium when it has been known the number of moles of the reacting agent, but can’t construct the stoichiometric concepts of equilibrium |
| 14              | Predict the concentrations of reactants to be added if known Kc          | Student knows that he concentration of all products divided by the concentration of the gas-phase reactant is removed by the coefficient number, but can’t predict the concentrations of reactants to be added if known Kc |
| 15              | predicting the concentration of each substance in a state of equilibrium | Student can’t predict the concentration of each substance in a state of equilibrium, but knows that the number of moles of the product and reactant is directly proportional to the reaction coefficient |

Table 8 shows that student 6 from low ranked school have misconception in question number 4, 7, 12, 13, 14 and 15, on the all of three subtopic in chemical equilibrium. Based on the results of the above, the third subtopic most cause misconceptions. In third topic the question is very related to mathematical calculations. It means that there are correlations between their mathematics skills and students' misconceptions in chemical equilibrium.

Misconception is not only caused by students' mistakes, but can also be caused by inappropriate teaching methods, this is what school made misconceptions. Therefore the teacher must be up to date to stop improper teaching methods [19].

Diagnosis of student misunderstandings more precisely and suitable for a large number of surveys can use diagnostic tests with structured methods [20]. This study adopted two-tier test developed by Treagust (1985) and implemented a computerized system to detect student misconceptions so as to improve learning. Effective learning strategies for combating student misconceptions will depend on the results of identification of sources of misconception[18]. Once misconception is more easily identified, chemical equilibrium will be more likely to be improved by developing alternative teaching approaches that overcome of student’s misconception.

4. Conclusion
There is subtopic on the concept of chemical equilibrium that most likely causes misconception that is, interpreting the experimental results in equilibrium state. Students profiles of misconception can be
used for detect difficulty learning chemistry for students. After a misconception of each individual student is identified, chemical equilibrium will be more likely to be enhanced by developing an alternative teaching approach that overcomes student misconceptions.

References
[1] Bergquist W and Heikkinen H 1990 Student ideas regarding chemical equilibrium: What written test answers do not reveal J. Chem. Educ. 67 12 p 1000
[2] Voska K W and Heikkinen H W 2000 Identification and Analysis of Student Conceptions Used to Solve Chemical Equilibrium Problems J. Res. Science Teach 37 2 pp 160–176
[3] Gorodetsky M and Gussarsky E 1986 European Journal of Science Misconceptualization of the chemical equilibrium concept as revealed by different evaluation methods Misconceptualizatio of the chemical equilibrium concept as revealed by different evaluation methods Eur. J. Sci. Educ. 8 pp 427–441
[4] Modell H, Michael J and Wenderoth M P 2005 Helping the Learner To Learn: The Role of Uncovering Misconceptions Am. Biol. Teach. 67 1 pp. 20–26
[5] Naklehle M 1992 Why Some Students Don’t Learn Chemistry Chemical Misconceptions J. Chem. Educ. 69 pp. 191–196
[6] Banerjee A C 1991 Misconceptions of students and teachers in chemical equilibrium Int. J. Sci. Educ. pp. 37–41
[7] Novak J D 1971 Learning, Creating, and Using Knowledge: Concept maps as facilitative tools in schools and corporations J. e-Learning Knowl. Soc. 6 pp. 21–30
[8] Treagust D F 1988 Development and use of diagnostic tests to evaluate students’ misconceptions in science Int. J. Sci. 10 pp. 159–169
[9] Osborne R J and Gilbert J K 2007 A Method for Investigating Concept Understanding in Science A Method for Investigating Concept Understanding in Science European Journal of Science February pp. 37–41
[10] Chwee L S, Tan K, Goh D, Chia N K and Treagust D F Development and Application of a Two-Tier Multiple Choice Diagnostic Instrument to Assess High School Students Understanding of Inorganic Chemistry Qualitative Analysis 39 4 pp. 283–301
[11] Adadan E and Savasci F 2012 An analysis of 16 – 17-year-old students understanding of solution chemistry concepts using a two-tier diagnostic instrument Int. J. Sci. Educ. 34 pp. 37–41
[12] 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 reactions using multiple levels of representation R. Soc. Chem. 8 3 pp 293–307
[13] Akkus H and Kadayifci H 2011 Development and Application of a Two-Tier Diagnostic Test to Assess Secondary Students’ Understanding of Chemical Equilibrium J. f Balt. Sci. Educ. 10 pp. 146–155
[14] Tyson L, Treagust D F, and Bucat R B 1999 The Complexity of Teaching and Learning Chemical Equilibrium J. Chem. Educ 76 4
[15] Treagust D F and Centre M E 1998 Diagnostic assessment in science as a means to improving teaching, learning and retention UniServe Sci. Assess. Symp. Proc. pp. 1–9
[16] Tsai C and Chou C 2002 Diagnosing students’ alternative conceptions in science J. Comput. Assist. Learn. 18 pp 157–165.
[17] Yamtinah S, Saputro S and Mulyani B Item Discrimination Of Two Tier Test On Hydrolysis Of Salt 2016 Proceeding International Conference Educational Research and Evaluation pp 360–365.
[18] Abraham M R, Grzybowski E B, Renner J W and Marek E A Understandings and Misunderstandings of Eighth Graders of Five Chemistry Concepts Found in Textbooks 1992 J. Research Sci. Teach. 29 2 pp 105–120
[19] Barke S Y H and Hazari A 2009 Misconceptions in Chemistry schnell und portofrei erhältlich bei
Students’ Misconceptions and How to Overcome Them (Verlag Berlin Heidelberg, Springer) p. 1-7

[20] Lai A 2007 The Development of Computerized Two-tier Diagnostic Test and Remedial Learning System for Elementary Science Learning Seventh IEEE Int. Conf. Adv. Learn. Technol. 81 p. 31-53