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Analysis of High School Students Misconceptions Using Four-Tier Multiple Diagnostic Test on Chemical Equilibrium Material

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ABSTRACT

Chemical equilibrium is one of the concepts in chemistry that often leads to misconceptions. A study was conducted to investigate students misconceptions on the topic of chemical equilibrium using a four-tier diagnostic test instrument. This research aims to analyze the level of misconceptions among students regarding the complex and challenging chemistry material, which results in misconceptions, specifically chemical equilibrium. The research method employed is a descriptive quantitative. The subjects of this study were 100 high school science students from SMAN 1 Gambut and MAN 3 Banjar in the Banjar Regency for the academic year 2023/2024. Data collection was carried out using a four-tier diagnostic test instrument consisting of 12 questions, categorizing the understanding of concepts into four categories: complete understanding, partial understanding, lack of understanding, and misconceptions. Data analysis techniques involved converting the results of the students' four-tier diagnostic test into percentage data. The results showed that at SMAN 1 Gambut, 14.29% of students experienced misconceptions, whereas at MAN 3 Banjar, 16.09% of students experienced misconceptions. The dynamic equilibrium material had the highest misconception rate at 18.31%, while the equilibrium shift material had the lowest misconception rate at 11.76%. It was concluded that students' misconceptions fall into the low category. It is recommended to conduct further research with a larger and more diverse sample to obtain more comprehensive data and better generalizations regarding students misconceptions.

INTRODUCTION

Chemistry is one of the complex science disciplines because it has a lot of abstract concepts and topics, which can often be difficult for students to understand. These difficulties are caused by the abstract properties of many chemical concepts, therefore students often find it difficult to connect chemical concepts that cannot be observed directly with concrete reality reality (Osborne & Dillon, 2008). To address this difficulty, chemistry lessons are usually presented in three levels of representation: macroscopic, submicroscopic, and symbolic. These approaches are expected to help students understand chemical concepts that are complex and abstract. (Pongkendek & Kristyasari, 2022).

One of the notable chemistry materials with a variety of abstract concepts is chemical equilibrium. Which stated that based on an analysis of misconceptions using the Rasch measurement model and the percentage of misconceptions, students experienced many misconceptions about chemical equilibrium material (Suparman, Rohaeti, & Wening, 2024). This concept includes various subconcepts such as dynamic equilibrium, homogeneous and heterogeneous equilibrium, as well as the concept of equilibrium constant. In addition, this concept is also closely related to other chemical concepts, such as reaction rate, acid-base concept, and solution equilibrium (Akbar, Herdini, & Abdullah, 2019). The concept of chemical equilibrium has an important role because it is not only relevant in everyday life, but

also the basis for various industrial and technological applications. However, understanding this concept is often challenging, mainly due to its abstract nature and its interrelationship with other concepts (Sugiarti & Sukarmin, 2019).

Inaccurate understanding of abstract chemical concepts often causes misconceptions among students. These misconceptions occur when students' understanding deviates or contradicts the correct scientific concept, which may hinder their further learning process (Al-fatihah, Isnaini, & Laksono, 2022). These misconceptions result in low student learning outcomes and interfere with their understanding of the follow-up chemistry materials (Ginting, 2021). In addition, research shows that misconceptions often occur due to errors in the delivery of material, through printed and electronic media, as well as mistakes in explanations from teachers or lecturers (Suparno, 2013).

Previous studies have found that misconceptions often occur in chemical equilibrium material. For example, 30.97% misconceptions were found in the concept of dynamic equilibrium, 22.82% in the equilibrium constant, and 52.10% in the equilibrium shift (Pujianto, Masykuri, & Utomo, 2018). In addition, the research from (Permatasari, et al., 2022) also found that the misconceptions experienced by students on chemical equilibrium material ranged from 43.91%-62.06%, especially on the concept of equilibrium constant and Le-Chatelier Principle. Misconceptions can be defined as misunderstandings of phenomena that occur in the real world that are not in accordance with scientific explanations of these phenomena. Identifying misconceptions is an important step in overcoming this problem. Various methods can be used to identify misconceptions, including the use of diagnostic tests. One of the widely used diagnostic tests is the multiple choice test, which is easier to implement and cost-effective (Yamtinah, et al., 2019). Diagnostic tests are considered the most appropriate method for identifying misconceptions, as other methods like interviews are less accurate when dealing with large student groups and general responses (Ashfarini & Rahmawan, 2024). However, traditional one-tier multiple choice tests are often less effective because students still have the opportunity to answer correctly by guessing (Fauziyah, 2019). The study by (Soeharto & Csapo, 2021) reinforces the urgency of using diagnostic instruments that can identify misconceptions in a specific and structured manner. Therefore, the development of more advanced diagnostic instruments is important.

Diagnosing students' learning difficulties involves more than just diagnostic tests, including exploring the types, sources, and causes of errors. A good diagnostic test can identify students' misconceptions and help teachers and students better understand the concepts (Laksono, 2020). One of the diagnostic instruments developed to resolve the limitations is the four-tier multiple-choice diagnostic test. This test consists of four levels, where students are not only asked to choose the correct answer, but also include their reasons and level of confidence in the answer (Agustin, Susilaningsih, Nurhayati, & Wijayati, 2022). Addressing misconceptions should be done as early as possible, and this can be more effective when their underlying causes are accurately identified (Mayasri, Reza, & Nasir, 2023).

This research aims to determine students' misconceptions about chemical equilibrium material using a four-tier multiple diagnostic test. Implementing a more accurate diagnostic test is expected to help identify and overcome misconceptions, allowing chemistry learning to be more effective and students to understand chemical concepts in a deeper and correct way.

METHODS

Research Design

This research uses a quantitative-qualitative method approach and a descriptive research design. Descriptive research describes research that aims to investigate the state of things that are presented in a straightforward and clear manner. Exploratory descriptive research

specifically aims to describe the condition of a phenomenon; this research is not intended to test certain hypotheses but only to describe what a variable, symptom or situation is (Arikunto, 2015).

Research Target

This research was held in June 2024 at two schools in Banjar Regency, South Kalimantan: SMA Negeri 1 Gambut and MAN 3 Banjar. The location was selected based on accessibility and the suitability of students' characteristics with the research objectives. The population in this study was all students of SMA Negeri 1 Gambut and MAN 3 Banjar who had studied chemical equilibrium materials.

Research Data

The sampling technique used is purposive sampling, which involves sampling based on certain considerations such as limited time and resources (Arikunto, 2015). The sample consisted of two classes in each school, which were selected by considering the representation of different levels of academic ability.

Research Instruments

The main instrument of this research is a four-tier multiple-choice diagnostic test designed to identify students' misconceptions about chemical equilibrium material (Syahmani, Suyono, & Supardi, 2020). The instrument's validity was tested using content validity with Aiken's V formula, while reliability was tested using the Kuder Richardson 20 (KR-20) method to ensure the consistency of measurement results (Azwar, 2016).

Data Analysis

Data was collected through a four-tier multiple-choice diagnostic test administered to learners online using Google Forms. The test consists of four tiers: the student's answer, conviction in the answer, the reason for choosing the answer, and conviction towards the reason. (Agustin, Susilaningsih, Nurhayati, & Wijayati, 2022). Data were analysed using a quantitative descriptive method. The percentage of misconceptions was calculated using the percentage formula for each conceptual understanding, understanding, and misconception category, grouped based on the categories determined in Table 1.

Table 1. Misconception Grouping

No	Category	Option	Conviction Level	Reason	Conviction Level
1	Misconception (M)	False	Convinced	False	Convinced
2	Not Understanding the Concept (NUC)	False	Convinced	False	Not Convinced
3		False	Not Convinced	False	Convinced
4		False	Not Convinced	False	Not Convinced
5	Understand the Concept (UC)	True	Convinced	True	Convinced
6	Partially Understood (PU)	True	Convinced	True	Not Convinced
7		True	Not Convinced	True	Convinced
8		True	Not Convinced	True	Not Convinced
9		True	Convinced	False	Convinced
10		True	Convinced	False	Not Convinced
11		True	Not Convinced	False	Convinced
12		True	Not Convinced	False	Not Convinced
13		False	Convinced	True	Convinced

No	Category	Option	Conviction Level	Reason	Conviction Level
14		False	Convinced	True	Not Convinced
15		False	Not Convinced	True	Convinced
16		False	Not Convinced	True	Convinced
17	Not Codable (NC)		If anyone, two, three or all are missing		

(Amin, Wiendartun, & Samsudin, 2016)

The test results were then categorised based on the criteria set, which were low, medium, and high misconceptions, as described in Table 2.

Table 2: Misconception Criteria

Percentage of Misconceptions	Misconception Criteria
0 < Misconception≤30%	Low
30% < Misconception≤ 70%	Medium
70% < Misconception≤ 100%	High

(Edasa, 2018)

RESULTS AND DISCUSSION

Based on the research results, several data were obtained, such as the results of the misconception analysis and the level of misconceptions of students on chemical equilibrium material using the four-tier diagnostic test instrument. The results of the validation of the four-tier diagnostic test instrument given by the assessor team on the chemical equilibrium material test instrument, it is known that each item has an Aiken's coefficient value with a range of 0.8 <V which indicates that each item of the instrument is valid, so it is suitable for use in this study.

In addition to the validity test, the instrument is reliable if it provides fixed or consistent results when tested many times. (Rudini, 2020). After validating the test instrument, the researcher conducted a reliability test. In this study, reliability was measured using the KR-20 formula. The calculation results on the four-tier diagnostic test instrument reliability coefficient of 0.82, which means it is included in the very high category. Therefore, this four-tier diagnostic test instrument can be declared suitable for use in research.

The analysis of misconception results on chemical equilibrium material from two schools, SMAN 1 Gambut and MAN 3 Banjar, revealed significant differences in students' understanding of the concept. Based on the available data, at SMAN 1 Gambut, 14.29% of students had misconceptions, 40.63% understood the concept, 16.22% did not understand the concept, and 28.87% partially understood. On the other hand, at MAN 3 Banjar, 16.09% of students had misconceptions, 68.99% understood the concept, 7.36% did not understand the concept, and 7.56% partially understood, as shown in Figure 1.

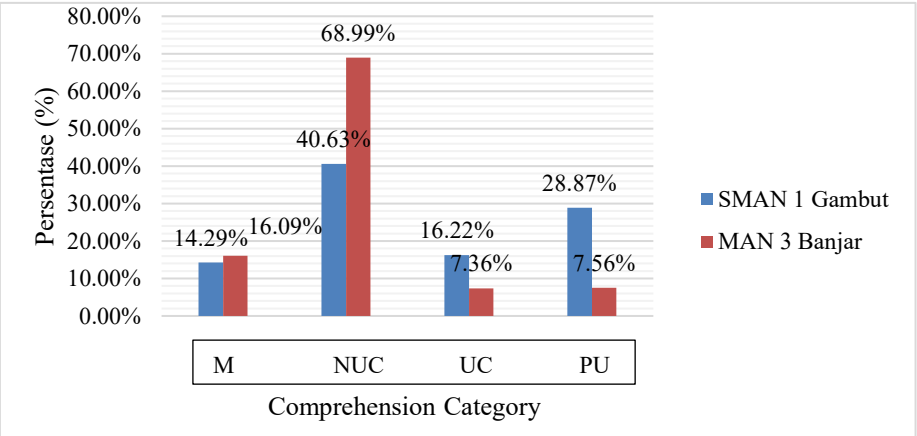

Figure 1. Comparison of the Sample School's Comprehension

Progress in understanding the concept of chemical equilibrium in both schools is evident; there is room for improvement, especially in overcoming misconceptions and improving the understanding of students who do not understand the concept. By evaluating and improving teaching methods and giving more attention to students who have difficulties, it is hoped that the understanding of chemical equilibrium concepts can be improved equally in both schools. The study also underscores the importance of a more individualized approach to teaching, where each student is given attention according to their needs to ensure that no one is left behind in understanding the concepts taught. (Putro, et al., 2023).

A more in-depth analysis was carried out on the presentation of misconceptions based on the principal material. The principal material is a core component in learning chemistry which includes various basic concepts and principles that must be understood by students, in this study the subject matter in the test is limited only to the material (dynamic equilibrium, homogeneous and heterogeneous equilibrium, equilibrium constant, quantitative relationship between components in equilibrium reactions, and equilibrium shifts). By analyzing misconceptions based on the subject matter, researchers can see which concepts students most misunderstand. This information is very useful for designing more effective learning strategies to improve students' understanding of important concepts in chemical equilibrium. The misconceptions of students based on the subject matter are presented in Table 3 below.

Table 3. Misconceptions Based on Subject Matter

Subject Material	M	NUC	UC	PU	Misconception
A (1)	18,31%	69,62%	3,84%	8,22%	• Students assume that dynamic equilibrium is equilibrium that has the same mass of reactants and products.
B (2)	16,72%	72,38%	3,84%	7,06%	• Students still have difficulty in determining which is heterogeneous equilibrium.
C (3-4)	13,09%	39,74%	14,39%	32,78%	• Students still have difficulty determining the substances involved in the calculation of the equilibrium constant.
D (5-7)	20,73%	43,19%	13,34%	22,74%	• Many students still have difficulty in determining the substances involved and the calculations.
E (8-12)	11,76%	61,33%	13,01%	13,90%	• Students experienced misunderstandings in the equilibrium shift subconcept, namely assuming that if there is an increase in reactant concentration, the product concentration remains and the reactant concentration decreases. • Students assume that if the pressure is increased then the equilibrium shifts towards the larger coefficient. • Students assume in endothermic reactions that if the temperature is increased, the equilibrium will shift to the left. • Students assume that the role of the catalyst is to increase the activation energy to speed up the achievement of equilibrium.
Average	16,12%	57,25%	9,68%	16,94%	

Table 3 shows data based on the subject matter, showing that in material A (dynamic equilibrium), misconceptions reached 18.31%, while concept understanding reached 69.62%. Material B (homogeneous and heterogeneous equilibrium) has a misconception rate of 16.72% and concept understanding of 72.38%. In material C (equilibrium constant), misconceptions amounted to 13.09%, and concept understanding amounted to 39.74%. Material D (quantitative relationship between components in equilibrium reactions) showed a misconception rate of

20.73% and concept understanding of 43.19%. Finally, material E (equilibrium shifts) has a misconception rate of 11.76% and a concept understanding of 61.33%. The overall average misconception rate is 16.12%, with a concept understanding of 57.25%. The percentage of learner categories for each subject matter is shown in Table 4 below

Table 4. Percentage of Students' Misconception Categories for Each Subject Matter

Subject Material	Percentage of Misconception	Misconception Categories
Dynamic equilibrium	18,31%	Low
Homogeneous and heterogeneous equilibrium	16,72%	Low
Equilibrium constant	13,09%	Low
Quantitative relationships between components in equilibrium reactions	20,73%	Low
Shifting equilibrium	11,76%	Low

In the dynamic equilibrium material (A), 18.31% of students experienced misconceptions. This shows that dynamic equilibrium, which involves understanding how the reaction continues despite no macroscopic changes in the system, is still quite difficult for some students. Homogeneous and heterogeneous equilibrium (B) has a misconception rate of 16.72%. In the equilibrium constant (C), the misconception rate is 13.09%, the lowest percentage among other subject matters. This indicates that students are better at understanding the concept of the equilibrium constant, which includes how this constant is used to calculate the equilibrium concentrations of reagents and products. In the equilibrium shift material (E), the misconception rate is 11.76%, the second lowest percentage.

The highest misconception was found in the quantitative relationship between components in the equilibrium reaction (D), with a percentage of 20.73%. This shows that many students have difficulty in understanding and applying the principles of stoichiometry in the context of chemical equilibrium. In this study, it was found that many students still have difficulty in determining the substances involved and calculating the equilibrium constant. The study by Abdullah, Azmi, and Ardiansyah (2021) found that most high school students still cannot find the correct approach to solving chemistry calculation problems. Transformation errors may be caused by the students' inability to apply the information in the question to the correct equation. Recent research by Rosida, Widarti, and Yahmin (2022) showed that misconceptions about chemical equilibrium materials, including quantitative relationships between reaction components, are still common among high school students. The study by (Andriani, Mulyani, & Wiji, 2023) identified prevalent misconceptions related to chemical equilibrium, particularly concerning its dynamic nature, the stability of the equilibrium constant, and the factors influencing shifts in equilibrium. These concepts, dynamic equilibrium, equilibrium constant, and Le Chatelier's principle, are frequently perceived as cognitively demanding, unfamiliar, and linguistically challenging, contributing to students' conceptual difficulties. The diagnostic test in this study identified that mistakes are often caused by students' inability to connect concepts at the microscopic, macroscopic and symbolic levels, which makes it difficult for them to understand molar concentration in equilibrium reactions (Novita, Suyono, & Suyatno, 2023).

This study found that the average level of misconceptions held by students for chemical equilibrium material was 0 < Misconception ≤30%. The results of this study indicate that the misconceptions of students fall into the low category and it was found that this has results that are in line with research conducted by (Timanoyo, Effendy, & Nazriati , 2020) which shows that students' misconceptions regarding factors affecting chemical equilibrium shifts have an average percentage below 30%. And the study conducted by (Nufus & Silfianah, 2023) shows

that students' misconceptions occur with an average percentage of 20%. As a whole, this data shows that while there are certain areas where students have a better understanding, such as on the equilibrium constant and equilibrium shifts, there are also areas that require more attention, especially on the quantitative relationship between components in equilibrium reactions. (Agustin, Susilaningsih, Nurhayati, & Wijayati, 2022).

CONCLUSION AND RECOMMENDATIONS

Based on the research results and discussion, it can be concluded that the level of misconceptions of students on chemical equilibrium material using the four-tier multiple diagnostic test at SMAN 1 Gambut and at MAN 3 Banjar shows variations in understanding of the concept of chemical equilibrium between the two schools. The dynamic equilibrium material has the highest level of misconception, while the equilibrium shift material has the lowest level of misconception. The average misconception students hold for chemical equilibrium materials is below thirty percent. The results of this study indicate that students' misconceptions are in the low category. Further research with a larger and more diverse sample is recommended to obtain more comprehensive data and better generalisations related to students' misconceptions.

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