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Identification of Students' Conception Profile on Chemical Equilibrium Material Using 4TMC Diagnostic Test Instrument

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Abstract: Identification of Students' Conception Profile on Chemical Equilibrium Material Using 4TMC Diagnostic Test Instrument. Objectives: This study aims to identify students' conceptions of chemical equilibrium material using the 4TMC diagnostic test instrument. **Methods:** Pre-experimental research with a one-shot case study design by giving treatment to a group of students and then observing the results obtained. **Findings:** Some students still experience conceptual errors in chemical equilibrium material. In the concentration factor, students were identified as understanding the concept by 15.3%, not understanding the concept by 43.3%, and misconceptions by 41.4%. In the pressure and volume factors, students were identified as understanding the concept by 16.7%, not understanding the concept by 52%, and misconceptions by 31.3%. In the temperature factor, learners were identified as understanding the concept by 22.7%, not understanding the concept by 48.7%, and misconceptions by 28.6%. **Conclusion:** Based on the results and discussion of the research, it can be concluded that the development of the 4TMC diagnostic test instrument developed can identify the conceptions of students on chemical equilibrium material. Diagnostic test instruments are important to use as an evaluation material of the learning process carried out by the teacher.

Keywords: identification, conception profile, 4TMC diagnostic test.

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INTRODUCTION

According to Mortimer (1979), chemistry is defined as a science that deals with the characterization, composition, and transformation of matter. Chemistry is often considered difficult because it is abstract with complex calculations, terms that are rarely found in everyday life, and has various representations used by experts in explaining chemical phenomena that occur. Between one chemical concept and other concepts are interrelated, so understanding concepts in learning chemistry is very important so that there are no errors in understanding concepts on an ongoing basis. Understanding the concept of a material is referred to as conception.

Berg (1991) explains hat conception is an individual interpretation of a scientific concept. There are several categories of conceptions that students have when understanding a learning material. If students have a conception that is in accordance with scientific concepts, it is called understanding the concept. If students have an understanding that is not in accordance with scientific concepts, it is called not understanding the concept. Students' misunderstanding of a scientific concept results in an incorrect interpretation and is not in accordance with the actual concept, so that it can lead to misconceptions. Winarni and Syahrial (2016) explained that misconceptions are understandings

that are not in accordance with the understanding accepted by scientific experts. When students have a wrong understanding and are consistent, then students are said to experience misconceptions.

To find out the conceptions of students in this material, a proper instrument is needed to help teachers identify students' conceptions. The right instrument is a diagnostic test, in agreement with Treagust (2010) who revealed that diagnostic tests are a good method for identifying students' misconceptions in learning.

Four-tier multiple choice (4TMC) is defined as a four-tier multiple choice diagnostic test used to diagnose misconceptions. Ismail (2015) revealed that there is confidence in choosing answers and reasons in the four-tier test so that students' answers can be identified more deeply. This four-tier diagnostic test improves the three-tier test that was previously developed. In the four-tier multiple choice (4TMC), tier one contains questions and choices, tier two contains the level of confidence when answering the first tier questions, tier three contains the choice of reasons in answering the first tier, and tier four contains the level of confidence in choosing the reasons in the third tier (Agustin et al., 2022).

There have been many studies on the development of the four-tier test instrument. Caleon and Subramaniam (2010) revealed that the 4TMC test can be used to diagnose the strength of students' concepts of a material. The 4TMC instrument is more sensitive and stronger than other multiple choice questions. Fariyani, et al (2015) also explained that the four-tier test can diagnose misconceptions experienced by students on certain concepts. The research conducted by Izzah and Madlazim (2019) produced a diagnostic test instrument to detect misconceptions with a four-level format on Newton's law of gravitation material. This instrument has a reliability value of 0.843, so it is declared reliable to use. Meanwhile, research conducted by Utami Agustin, et al (2022) produced a diagnostic test instrument that is feasible to use for chemical equilibrium material with a four-tier multiple choice format. The instrument covers all concepts of chemical equilibrium material, ranging from the concept of equilibrium to the principle of equilibrium in industrial processes.

Based on the description of the importance of identifying students' conceptions to determine the level of understanding of chemical equilibrium material, especially on factors that affect the equilibrium shift, the researchers are interested in identifying the conception profile of students on chemical equilibrium material using the 4TMC diagnostic test instrument.

METHOD

Participants

The limited trial was conducted on 30 students of class XII IPA 1 SMAN 16 Surabaya. The sample was taken based on the results of observations made, where students are known to have heterogeneous cognitive abilities, so that diagnostic test testing can be done to identify the category of students' conceptions more deeply. The implementation of this limited trial was assessed using the research instrument that had been developed.

Research Design and Procedures

This research is pre-experimental research with a One-Shot Case Study design. In the One-Shot Case Study design, a group is given treatment or treatment, and then the results are observed (Sugiyono, 2018).

The initial procedure carried out in this study was to develop a 4TMC diagnostic test instrument. The instrument consists of 15 question items, each of which has a question indicator to assess students' conceptions of the material of factors that affect the shift of equilibrium. Furthermore, the 4TMC diagnostic test that has

been prepared is then carried out in a validation stage carried out by experts to assess the validity of the instrument developed.

When the 4TMC instrument has gone through the validation stage from experts and received input, then improvements are made to the 4TMC instrument developed so that the instrument is ready for use. The next step was a limited trial on 35 students by giving the 4TMC diagnostic test questions. The trial was conducted in two meetings, where the first meeting was a diagnostic test of 4TMC concentration, pressure, and volume factors while the second meeting was a diagnostic test of 4TMC temperature factors.

After students work on diagnostic test questions for all factors that affect the shift in equilibrium, the trial results are obtained in the form of a combination of student answers. Furthermore, the instrument reliability test was carried out to determine the level of reliability of the 4TMC instrument developed. In addition, the identification of students' conceptions is also carried out based on the results of the combination of answers obtained.

Instrument

The instrument used in this study is a four-tier multiple choice (4TMC) diagnostic test instrument. The 4TMC instrument developed is an adaptation of previous research. This research focuses on chemical equilibrium material, especially the concept of factors that affect equilibrium shifts. Based on Le Chatelier's principle, chemical equilibrium shifts can be influenced by concentration, pressure, volume, and temperature factors.

The developed 4TMC diagnostic test instrument contains 15 question items which are divided into 3 parts, namely concentration factor questions, pressure and volume factor questions, and temperature factor questions. Each factor consists of 5 items, where each item consists of four tiers in it. Each factor contains three chemical representations, namely macroscopic, submicroscopic, and symbolic representations so that student's understanding of the concept of chemical equilibrium can be known more deeply. The 4TMC diagnostic test instrument developed will go through a validation stage to determine the validity of the question instrument. In addition, the reliability test of the instrument is also carried out based on the data obtained from student answers.

Data Analysis

Based on the data from the trial results, the students' conception profile was analyzed. Learners' answers when working on the 4TMC diagnostic test are then interpreted in the location of their conception through the following table:

Table 1. Interpretation of student answer combination results

Answer	Answer Confidence Level	Reason	Reason Confidence Level	Criteria
Correct	High	Correct	High	Understand the Concept
Correct	Low	Correct	Low	Doesn't Understand the Concept
Correct	High	Correct	Low	
Correct	Low	Correct	High	
Correct	Low	Wrong	Low	
Wrong	Low	Correct	Low	
Wrong	Low	Wrong	Low	
Correct	High	Wrong	Low	
Wrong	Low	Correct	High	

Correct	Low	Wrong	High	
Correct	High	Wrong	High	
Wrong	High	Correct	Low	
Wrong	High	Correct	High	Misconceptions
Wrong	High	Wrong	Low	
Wrong	Low	Wrong	High	
Wrong	High	Wrong	High	

In the developed 4TMC diagnostic test, the third tier contains the reasons for choosing the answer in the first tier. In the third tier, there are 5 choices of reasons in the form of multiple choices A, B, C, D, E and 1 free choice, namely F where learners can write their own reasons for answering the first tier. Reason option F can be filled in by learners if learners have other reasons outside the multiple choices provided in the third tier. The choice of reason F is supporting data for students' misconceptions, where students' answers to the reason F will then be further analyzed to determine the level of students' understanding of the material tested.

In the 4TMC diagnostic test, 6 confidence rating scales are used. The use of a confidence level scale from 1-6 aims to make students' confidence in answering the first and third tiers more specific depending on how confident students are in answering. The following is the classification of confidence levels on the diagnostic test instrument developed:

Table 2. Confidence level classification

Scale	Description	Confidence Level
1	Just guessing	Low
2	Very unsure	
3	Not sure	
4	Sure	High
5	Very sure	
6	Very sure	

The test results obtained are used as a basis for determining the category of conception level owned by students according to table 1. Furthermore, the percentage for each category of students' conceptions was calculated.

■ RESULT AND DISCUSSION

The 4TMC diagnostic test instrument developed has gone through a validation process from experts, so that the instrument can be said to be feasible based on aspects of content, construct, and language validity. Instruments that have gone through the validation process can then be tested on students.

In the implementation of limited trials, the 4TMC diagnostic test instrument developed was tested on students with heterogeneous abilities. These students are students who have previously received chemical equilibrium material at school. The 4TMC diagnostic test aims to identify the students' conception profile on the material.

Learners work on each item for each factor that affects the shift in equilibrium, namely the concentration factor, pressure and volume, and temperature. Each factor consists of 5 items which include macroscopic, submicroscopic, and symbolic representations, so that the total items on the diagnostic test developed are 15 questions. Each student's answer is then categorized into 3 categories of conception, namely understanding the concept, not understanding the concept, and misconceptions as in Table 1. In each item, the percentage of students' conceptions is calculated based on the answers they choose.

Based on the results of the trial using the 4TMC diagnostic test instrument, the results of the students' conception profile are presented in the following table.

Table 3. Conception profile of learners concentration factor

Question Number	Conception Profile		
	Understand the Concept	Doesn't Understand the Concept	Misconceptions
1	26.7%	30%	43.3%
2	30%	36.7%	33.3%
3	10%	50%	40%
4	3.3%	50%	46.7%
5	6.7%	50%	43.3%
Average	**15.3%**	**43.3%**	**41.4%**

Based on Table 3 above, it is known that in the concentration factor as many as 15.3% of students identified the category of understanding the concept, 43.3% of students identified the category of not understanding the concept, and 41.4% of students identified the category of misconceptions. This shows that in the concentration factor that can affect the equilibrium shift, most students still experience misconceptions. Learners were identified as having the greatest misconceptions in item number 4 which contains submiscopic representations. It is known that students still experience misconceptions on the concept of concentration changes that can result in changes in the number of particles in the new equilibrium system.

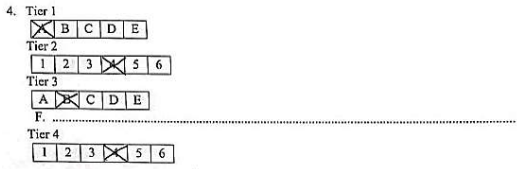

Figure 1. DSF students' misconception answers number 4

In question number 4 of the concentration factor, a picture of particles in the equilibrium system is presented. It is known that many students experience misconceptions when answering these questions because of errors in understanding the direction of the shift that affects changes in the number of reactant particles. In the question, it is known that there is an increase in the concentration of the reactant, so that the system will reduce the concentration of the reactant which makes the number of reactant particles, in this case O2, become less. When the concentration of reactants is increased, the equilibrium will shift towards the product. In this problem, many students still have difficulty in determining which substances will increase or decrease in number if the concentration is increased. Permanent equilibrium can occur when the forward reaction rate and the backward reaction rate are the same and when the concentration of products and reactants does not change anymore over time even though the concentration is not the same (Novita et al., 2023). Changes in the amount of products and reactants are a submicroscopic picture of the effect of changes in concentration on the system, but the system will reduce the effect of these actions.

Table 4. Learners' conception profile of pressure and volume factors

Question Number	Conception Profile		
	Understand the Concept	Doesn't Understand the Concept	Misconceptions
1	40%	40%	20%
2	13.3%	60%	26.7%
3	23.3%	50%	26.7%
4	23.3%	63.3%	13.4%
5	23.3%	46.7%	30%
Average	16.7%	52%	31.3%

Based on Table 4 above, it is known that in the pressure factor and as many as 24.7% of students identified the category of understanding the concept, 52% of students identified the category of not understanding the concept, and 23.3% of students identified the category of

misconceptions. This shows that in the pressure and volume factors that can affect the shift in equilibrium, there are some students who still experience misconceptions. Learners were identified as having the greatest misconceptions in item number 5 which contains submiscopic representations. It is known that students still experience misconceptions on the concept of pressure changes that can result in changes in the number of particles in the new equilibrium system.

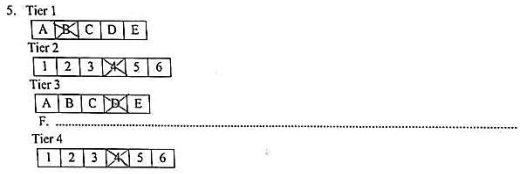

Figure 2. NAM students' misconception answers number 5

In question number 5, the pressure and volume factors, a picture of a molecule in an equilibrium state is presented. It is known that many students experience misconceptions when answering these questions due to errors in determining the number of moles in products and reactants. When the equilibrium system is disturbed, the equilibrium will shift and form a new equilibrium after a while (Novita et al., 2023). In this problem, the system pressure is increased, so that the number of molecules of both products and reactants will change due to a shift in equilibrium. The coefficient of the product is smaller than the reactant, so when the system is enlarged, the equilibrium will shift towards the product (right). When the equilibrium shifts towards the product, the number of molecules in the product will increase, while the number of reactants will decrease. The concepts of pressure and volume changes that are opposite to each other make students often confused in understanding these concepts.

Table 5. Conception profile of temperature factor learners

Question Number	Conception Profile		
	Understand the Concept	Doesn't Understand the Concept	Misconceptions
1	0%	43.3%	56.7%
2	30%	46.7%	23.3%
3	26.7%	50%	23.3%
4	20%	46.7%	33.3%
5	36.7%	56.7%	6.6%
Average	22.7%	48.7%	28.6%

Based on Table 5 above, it is known that in the temperature factor as many as 24.7% of students identified the category of understanding the concept, 49.3% of students identified the category of not understanding the concept, and 26% of students identified the category of misconceptions. This shows that in the temperature factor that can affect the equilibrium shift, some students still experience misconceptions. Learners were identified as having the greatest misconceptions in item number 1 which contained macroscopic representations. The question provided experimental results with color differences between tubes 1 and 2, so that the macroscopic representation can be obtained from direct observation (Ahmar et al., 2020; Gkitzia et al., 2020; Rizqiyyah & Novita, 2022; Sinaga, 2022). It is known that students still experience misconceptions on the concept of temperature changes that can cause changes in the color of a solution in a new equilibrium system.

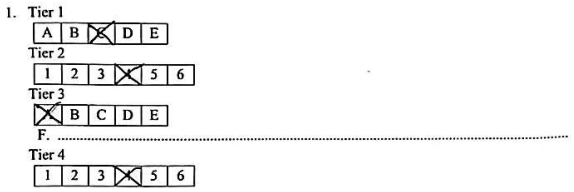

Figure 3. MTR students' misconception answers number 1

In question number 1, the temperature factor above, two pictures of experimental results are presented where there is a change in temperature in the system. It is known that some students experience misconceptions when answering this question because of mistakes in understanding the color changes that occur due to temperature changes. In the question, it is known that both solutions experience a color change due to a change in temperature that occurs in the system. In this question, some students do not understand the link between the equilibrium shift and the color change of a solution. It is known that students are also still difficult to distinguish which reactions shift towards exotherms and reactions that shift towards endotherms.

Based on Table 3, Table 4, and Table 5, it is known that the highest level of misconception occurs in the concentration factor which is 42.7%, while the percentage of misconceptions in the pressure and volume factors is lower at 31.3%. The lowest misconception occurred in the temperature factor, which amounted to 28.6%. In the concentration factor question, most students experienced misconceptions due to difficulties in determining the number of reactant and product particles when a system undergoes a shift in equilibrium. When the question occurs, there is an increase in concentration that can result in a shift in equilibrium. It is known that students still have difficulty in determining substances that will increase or decrease in number when a system experiences a change in concentration.

Based on the chemical representations contained in the 4TMC diagnostic test questions, it is known that students experience the largest macroscopic representation misconception, namely the temperature factor of item number 1. Students identified the largest submiscopic representation misconception, namely the concentration factor of item number 4.

Based on the results of the trials that have been carried out, it is known that the 4TMC diagnostic test instrument developed can identify the conceptions of students on the concept of chemical equilibrium, especially shifting equilibrium. Previous research conducted by Rayhanah (2020) found that 30.63% of students experienced misconceptions in the material of the direction of the shift based on Le Chatelier's principle. The percentage of misconceptions is the overall percentage of all factors that can affect the shift in the direction of equilibrium.

■ CONCLUSION

Based on the results and discussion of the research, it can be concluded that the development of the 4TMC diagnostic test instrument developed can identify the conceptions of students on chemical equilibrium material. Diagnostic test instruments are important to use as an evaluation material of the learning process carried out by the teacher.

The results of the study can be used as input and reference for teachers to identify students' conceptions of a material through the use of diagnostic test instruments. This is an effort to find out the level of students' conceptions so that teachers can identify concepts that have not been understood and need emphasis when the learning process is carried out. The 4TMC diagnostic test instrument developed is still in printed form, so it requires a lot of sheets when students do the diagnostic test. It is hoped that future researchers can develop a website-based four-tier multiple choice instrument that is easily accessible so that the diagnostic test becomes easier.

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