

ANALYSIS OF MISCONCEPTIONS AMONG TENTH GRADE STUDENTS ON BASIC CHEMISTRY CONCEPTS USING A TWO-TIER MULTIPLE CHOICE INSTRUMENT

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Abstract

This study aimed to identify the level of misconceptions held by tenth-grade students on the topic of the Fundamental Laws of Chemistry using a summative two-tier multiple-choice instrument, as well as to determine which conceptual areas were most frequently misunderstood. A descriptive quantitative research design was employed, involving Grade X students from a public senior high school in Malang as the research subjects. The instrument consisted of 15 two-tier multiple-choice items with reasoning. Instrument validity was examined using corrected item–total correlation analysis, showing that 14 out of 15 items had correlation coefficients greater than 0.30, while reliability analysis using Cronbach’s alpha yielded a coefficient of 0.840, indicating high internal consistency. Students’ responses were analysed by categorising them into three levels: understanding (U), misconception (M), and lack of conceptual understanding (LU). The results revealed that students experienced misconceptions across several concepts related to the Fundamental Laws of Chemistry, with the highest percentage occurring in Avogadro’s Law. This study contributes to secondary high school chemistry learning by providing a valid and reliable diagnostic instrument for identifying students’ misconceptions in fundamental chemistry concepts. Overall, the average percentages of students who demonstrated understanding, misconceptions, and lack of understanding were 71%, 24%, and 5%, respectively.

Key words: misconceptions, basic laws of chemistry, high school students

INTRODUCTION

Education can be defined as a form of communication between educators (teachers) and students with the aim of enhancing human potential. According to [1], education can be defined as a conscious effort to develop personality, intelligence, noble character, mental strength, skills, and self-confidence that are beneficial to individuals, society, the nation, and the state. Education provides insight and plays a crucial role in influencing, supporting, and protecting students throughout their development process, enabling them to complete life tasks independently without relying on others [2].

Education is the main foundation in the development process of a nation. Without a quality education system, achieving sustainable educational progress will be challenging. In the current era of globalization, several factors have influenced the world of education to become

increasingly diverse and complex. Attention needs to be paid to many aspects so that the implementation of education can produce quality that meets the demands of the times. It is inevitable that the methods used to improve the quality of education still face several obstacles that hinder the achievement of educational success [3].

Chemistry learning often faces various challenges because the material is considered abstract and complex, often resulting in conceptual difficulties for students. A number of studies reveal that misconceptions about basic chemistry concepts, such as the basic laws of chemistry and stoichiometry, contribute significantly to low academic achievement among students [4]. This finding is consistent with the results of a study conducted at SMAN 3 Bengkulu City, which included interviews with Tenth Grade Chemistry teachers and an analysis of students’ understanding of stoichiometry concepts [5]. The study reported

that students' scores on stoichiometry material tended to be low and identified the presence of misconceptions in several basic chemistry subtopics, with the lowest misconception percentage occurring in the concept of atomic mass and the highest occurring in mole interconversion and chemical calculation topics. These findings indicate that students' conceptual understanding remains an important issue that needs to be prioritised in the chemistry learning process. Therefore, a more effective learning approach is needed to minimise misconceptions and improve the overall quality of learning [6].

Misconceptions themselves are one of the factors that can affect the level of mastery of chemistry concepts. Misconceptions generally occur because of differences between the prior knowledge possessed by students and the actual scientific concepts. Therefore, in order to address these misconceptions, learning strategies are needed that can improve students' understanding of more scientific and accurate concepts [7].

Various factors can cause misconceptions, including students' prior experiences, the use of incorrect analogies, inappropriate learning methods, and the presentation of non-contextual material [8]. Therefore, it is important for teachers and researchers to analyse the types and levels of students' misconceptions in order to determine more effective learning strategies. One method widely used to detect misconceptions is the two-tier diagnostic test.

Diagnostic assessments play an important role in identifying students' potential, weaknesses, and levels of understanding of prerequisite material before learning new content [9]. In addition, such assessments help teachers to analyse in depth the learning difficulties experienced by students [10] and to design more systematic and effective learning interventions tailored to students' needs [11]. Two-Tier Multiple Choice (TTMC) is a form of multiple-choice question that differs from conventional formats by incorporating two levels of questioning. This type of question consists of two tiers, in which the first tier measures students' factual knowledge, while the second tier assesses the reasoning underlying their answers [12]. Research has shown that Two-Tier Multiple

Choice diagnostic assessments are developed to analyse students' misconceptions in the learning process [13]. The TTMC instrument reduces the likelihood of guessing, integrates phenomenological and conceptual domains within a single item, and enables more accurate identification of students' misconceptions than conventional multiple-choice tests, while remaining practical and time-efficient for classroom implementation [14][15].

This study focuses on analyzing misconceptions among tenth-grade students regarding basic chemistry concepts using a Two-Tier Multiple Choice instrument administered after learning activities. The test serves as a diagnostic summative test to describe students' conceptual understanding without comparing results before and after learning. The research was conducted in one class at a public high school in Malang City, with the aim of identifying the types and levels of students' misconceptions about basic chemistry laws as a basis for improving chemistry learning strategies at the secondary level. This research was based on existing problems among students, where motivation and interest in learning are still relatively low for basic chemistry material, which is still considered abstract and difficult to understand. This problem causes students to tend to only memorize formulas without understanding the underlying concepts. On the other hand, limited conceptual understanding and basic mathematical knowledge cause students to only answer questions procedurally without understanding the concepts in depth. Therefore, misconception analysis using the Two-Tier Multiple Choice instrument is needed to obtain a more in-depth picture of students' conceptual difficulties.

METHOD

This study employed a quantitative descriptive research design involving one class as the research subject. The quantitative approach was naturalistic, as the study was conducted under real classroom conditions without manipulation of variables or control of the learning environment [16]. This approach enabled a comprehensive examination of the learning phenomena and

provided insights into students' thinking patterns and conceptual understanding..

The population comprised tenth-grade students enrolled in the odd semester at a public senior high school in Malang City during the 2025/2026 academic year. The research sample was Class X-C, selected using a purposive sampling method, as the class met the criteria required for this study. As a result, not all members of the population had an equal opportunity to be selected..

Data were collected using a Two-Tier Multiple-Choice test administered after the completion of the learning activities. The instrument functioned as a summative assessment designed to identify students' levels of conceptual understanding of basic chemistry concepts rather than to measure learning gains. Students' conceptual understanding was classified based on the combination of responses in Tier 1 and Tier 2 of the two-tier test, as summarized in Table 1.

Table 1. Criteria for Classifying Students' Conceptions Based on the Two-Tier Multiple-Choice Test

Tier 1 Response	Tier 2 Response	Category
Correct	Correct	Understanding
Correct	Incorrect	Misunderstanding
Incorrect	Correct	Misunderstanding
Incorrect	Incorrect	Lack of misunderstanding

RESULTS AND DISCUSSION

Validity Test

The measure of an instrument's validity is called validity, which is the extent to which an instrument is able to measure the construct that should be measured accurately and in accordance with the measurement objectives [17]. Instruments with high validity are said to be valid, reliable, and suitable for use in the process of measuring learning outcomes. In this study, the validity of 15 two-tier multiple-choice items was tested using the corrected item–total correlation technique with IBM SPSS Statistics version 26. With 36 student respondents, the table r value at a significance level of 0.05 was 0.339. The questions can be declared valid if the calculated r value is \geq the table r value [18]. Based on the analysis results, it was found that 14 of the 15 questions were valid because they

had a correlation value of more than 0.339, namely questions q1 to q7, q9 to q15. Meanwhile, 1 question (q8) had a correlation value of 0.163, which was below the minimum criteria and was declared invalid. Thus, only 14 questions met the validity requirements and were used as instruments to collect data on student learning outcomes in the subject of Basic Chemistry. The following is a summary of the validity test results for the fifteen questions in Table 2.

Table 2. Item Validity of the Two-Tier Multiple-Choice Test

	Scale Mean if item Deleted	Scale Variance if items Deleted	Corrected items-Total Correlation	Cronbach's Alpha if item Deleted
q1	8,74	13,594	,515	,827
q2	8,65	13,932	,447	,831
q3	8,47	14,560	,383	,835
q4	8,41	14,431	,561	,829
q5	8,71	13,487	,555	,824
q6	8,71	13,184	,646	,819
q7	8,71	13,911	,431	,832
q8	8,76	14,852	,163	,848
q9	8,68	13,983	,420	,833
q10	8,68	13,377	,600	,822
q11	8,82	13,907	,416	,833
q12	8,79	13,320	,585	,822
q13	8,71	14,032	,396	,834
q14	8,91	14,083	,376	,836
q15	8,79	13,381	,567	,823

Reliability Test

Reliability testing is necessary to ensure the consistency of measurement results, namely the extent to which measurements of the same object can produce relatively constant or unchanged data [16]. Test reliability in this study was analyzed using SPSS 26.0 for Windows software with the Cronbach's Alpha method and measured on a scale of 0 to 1. There were 14 questions. The questions that were declared valid were tested for reliability and obtained a reliability value of 0.840. This indicates that the basic chemistry evaluation test questions have a very high level of reliability. The following are the results of the test reliability test in Table 3.

Table 3. Cronbach's Alpha Reliability of the Two-Tier Multiple-Choice Test

Cronbach's Alpha	N of Items
0,840	15

Data Collection

Percentage value in the question

Data from the assessment of student responses to each item from 36 tenth-grade students were obtained from the item measurement table in the Rasch model, as presented in the Appendix. Based on the results of this study, it can be said that there is variation in the percentage of student responses for the 15 questions presented in Table 4.

Table 4. Student Response Data

Question Number	Score	Data	
		Calculation	%
1	3	34	94
	1	2	6
	0	0	0
2	3	33	92
	1	3	8
	0	0	0
3	3	32	89
	1	3	8
	0	1	3
4	3	34	96
	1	1	2
	0	1	2
5	3	31	86
	1	5	14
	0	0	0
6	3	24	64
	1	13	36
	0	0	0
7	3	26	72
	1	10	28
	0	0	0
9	3	24	67
	1	10	28
	0	2	5
10	3	23	64
	1	6	17
	0	7	19
11	3	26	72
	1	10	28
	0	0	0
12	3	24	67
	1	10	28
	0	2	5
13	3	21	58
	1	14	39

Question Number	Score	Data	
		Calculation	%
14	0	1	3
	3	26	72
	1	8	22
15	0	2	6
	3	8	22
	1	23	64
	0	5	14

Based on Table 2, there is variation in the overall percentage of student responses. This shows that:

1. First, in all questions (1–15), there were students who scored 1, which indicates a misconception. This condition shows that some students were able to answer correctly but were unable to choose the conceptually appropriate reason, indicating that their understanding was not complete.
2. Second, a score of 0 also appeared on a number of questions, namely questions 3, 4, 9, 10, 12, 13, 14, and 15. This score indicates the category of not understanding the concept, where students answered incorrectly in both the answer and the reasoning. The appearance of a score of 0 on these items indicates that there are still significant conceptual obstacles related to the material being tested.
3. Third, there were no questions where all students scored 3 without any variation in scores. In other words, there were no questions that showed a uniform percentage in the concept understanding category. This indicates that for each question, there were still differences in the level of understanding among students, so that there were no concepts that were understood uniformly by all students.

Level of student misconceptions

The results of the study on students' misconceptions are shown in Table 5.

Table 5. Results of the Study on Students' Misconceptions

Main Topic	Subtopic	Question Number	Percentage of Misconception Categories		
			U	M	LU
Fundamental Chemical Laws	Law of Conservation of Mass	A1	94	6	0
		A2	92	8	0
		A3	89	8	3
	Law of Constant Proportion	A4	96	2	2
		A5	86	14	0
		A6	64	36	0
	Law of Multiple Proportions	A7	72	28	0
		A9	67	28	5
	Law of Comparative Volume	A10	64	17	19
		A11	72	28	0
		A12	67	28	5
	Avogadro's Hypothesis	A13	58	39	3
		A14	72	22	6
		A15	22	64	14

The results of the analysis of fourteen questions assessing students' understanding of basic chemistry law concepts showed varied outcomes. Items A1, A2, and A3, which assessed the law of conservation of mass, demonstrated high levels of understanding, with percentages of 90% for A1, 92% for A2, and 89% for A3. These results indicate that the law of conservation of mass is relatively easy to understand, as its statement is clear and its numerical application involves only basic arithmetic operations. This finding indicates that misconceptions related to the law of conservation of mass were the lowest compared to other basic chemistry law concepts assessed in this study. This result is consistent with the findings of [18], who reported that most students experienced minimal difficulty in understanding the law of conservation of mass due to its simple conceptual

structure and the use of basic arithmetic operations. However, a small proportion of students still exhibited misconceptions, accounting for 10% in A1, 6% in A2, and 8% in A3. One misconception identified in item A1 was the assumption that mass changes due to the formation of a precipitate, leading students to believe that the mass after the reaction is either greater or lower than before the reaction. In contrast, according to the law of conservation of mass (Lavoisier), the total mass of reactants and products in a closed system remains constant, as no substance is lost or created. Additionally, 4% of students in A2 and 3% in A3 were categorized as having no understanding.

In the Law of Constant Proportions (A4–A6), question A4 showed a high level of understanding at 96%, but in questions A5 and A6, the level of understanding dropped dramatically to 86% and 64%, with an increase in misconceptions to 14% in A5 and even 36% in A6, as well as 2% misunderstanding in A4 and A6. The misconceptions that arise in this category are generally related to errors in understanding that the mass ratio of elements in a compound is constant, so students often make mistakes when the sample mass is enlarged or reduced. Similar findings were reported by [19], who found that students commonly experience misconceptions related to the law of constant proportions, particularly in maintaining fixed mass ratios when the quantities of substances are increased or decreased, as identified through a four-tier diagnostic test. In A6, with the highest misconception rate of 36%, students do not understand the concept of limiting reactants and tend to assume that all reactants will be completely consumed in the reaction, consistent with previous findings reported in the literature that students do not understand the concept of limiting reactants and tend to assume that all reactants are completely consumed during a reaction [20]. Some students still misinterpret that the mass of the product is obtained from the sum of the masses of all reactants, without considering the fixed mass ratio of each element in a compound, consistent with the findings reported in a systematic review by [21], which identified this misconception as a common difficulty among students in understanding fundamental chemical laws,

particularly stoichiometry and the law of constant proportions. In fact, based on the stoichiometry of the reaction, O_2 is a limiting reactant, so only part of the Mg reacts, and the mass of MgO formed depends on the number of O_2 molecules available. This error indicates that students have not mastered the relationship between mass and fixed ratios and are unable to use balanced reaction equations to correctly determine the mass of products and remaining reactants. This indicates the need to strengthen students' understanding of basic stoichiometry concepts and their application in quantitative calculations.

In the Law of Multiple Proportions (A7–A9), the pattern of errors becomes more complex because this concept requires the ability to compare two different compounds composed of the same elements. A number of recent studies show that there is a misconception in basic chemistry, where in the Law of Multiple Proportions or Dalton's Law, there is a misconception among students who tend to only memorize a formula without understanding the conceptual requirements for its application [22]. Although student understanding is still dominant at 72% (A7) and 67% (A9), the percentage of misconceptions is quite high, namely 28% in A7 and 28% in A9, and misunderstanding reaches 5% in A9. The misconceptions in both questions are related to students' lack of understanding of the basis of the Law of Multiple Proportions, namely that this law only applies when two similar elements can form more than one compound and the mass of one element must be kept constant before comparing the mass of the other element so that a simple integer ratio is obtained [23]. In question A7, students often make the mistake of choosing a pair of compounds simply because their formulas appear similar or both contain two elements, without considering that the pair must be composed of the same element that forms two different compounds. In question A9, students tend to directly compare the total mass or the mass of X and Y without first equating the mass of element X, so that the comparison obtained does not show simple integers, which is a characteristic of Dalton's Law. The results of this study are in line with the results of a literature review which states that misconceptions in basic

chemistry laws occur due to a low level of conceptual understanding and procedural errors in solving mass comparison questions [24].

Furthermore, in the Law of Volume Comparison (A10–A12), students' understanding tended to decline by 64% (A10), 72% (A11), and 67% (A12), accompanied by misconceptions reaching 17% (A10), 28% (A11), and 28% (A12) and a lack of understanding of 19% in A10 and 5% in A12. Based on recent studies, it is still common to find misconceptions that the volume of gas is directly proportional to the mass of gas or that gases with a larger molecular mass have a smaller volume [25]. Meanwhile, Gay-Lussac's Law of Volume Proportions states that the ratio of the volumes of reacting gases and reaction products is determined by the reaction coefficients under the same pressure and temperature conditions, not by the mass of the gas. Given these misconceptions, it can be said that students are not yet able to conceptually distinguish between the concepts of mass, volume, and reaction coefficient, as also found in a study or research reporting that the law of gas volume ratio is among the most difficult subjects for high school students to understand [22].

In Avogadro's Hypothesis/Law (A13–A15), where student understanding was only 58% in A13, 72% in A14, and very low at 22% in A15, while misconceptions increased dramatically to 39% (A13), 22% (A14), and 64% (A15), and lack of understanding to 3% (A13), 6% (A14), and 14% (A15). Recent research shows that the biggest mistake in this category stems from the misconception that gases with different masses have unequal numbers of particles or volumes under the same conditions, as well as a failure to understand the relationship between volume and number of particles [25]. These findings confirm that students are not yet able to link macroscopic representations (visible phenomena), submicroscopic representations (particles), and symbolic representations (reaction equations), thus requiring multirepresentational learning strategies, an emphasis on visualizing particle processes, and continuous diagnostic evaluation to help students reconstruct concepts correctly and reduce deep-rooted misconceptions [26][27]. Based on the

overall concept of basic laws, the highest level of misconception occurred in the concept of Avogadro's law in question A15 with a misconception rate of 64%. This misconception factor was caused by several factors that could originate from students, teachers, or the learning resources used. Overall, the factors causing these misconceptions can be explained as follows:

a. Preconceptions or Incorrect Initial Concepts

One of the most dominant factors is the preconceptions that students bring with them before studying the material, as supported by [28], who emphasizes that students' prior conceptions play a central role in shaping how new scientific ideas are interpreted and learned. For example, students often assume that the volume of a gas is unrelated to the number of moles, or that all reaction coefficients indicate the amount of substance in any condition. Incorrect initial understandings such as these make new concepts difficult to absorb and ultimately persist as misconceptions.

b. Inappropriate Learning Methods and Strategies

Differences in students' learning styles influence their ability to understand abstract concepts in the fundamental laws of chemistry, particularly when concepts require the integration of symbolic, macroscopic, and submicroscopic representations; therefore, learning approaches that employ multiple representations are effective in supporting students' conceptual understanding [29]. In this study, the learning process employed a discovery learning model, supported by learning methods in the form of experiments, practicums, and group discussions. However, this study found that the implementation was not yet optimal in helping students build their understanding of concepts independently. Materials such as the relationship between gas volume (Gay-Lussac's Law) or molar ratios often require simultaneous skills in

symbolic, mathematical, and microscopic representation. Students who only memorize formulas without understanding the relationships between concepts, even after participating in practical activities and group discussions, tend to experience confusion and misinterpret data in story problems. According to [30], memorization without conceptual understanding limits students' ability to interpret information, make sense of quantitative relationships, and apply knowledge flexibly when solving contextual STEM problems.

c. Limited Mathematical Skills

Fundamental chemistry concepts are closely related to mathematical calculations, particularly proportions, comparisons, and the analysis of relationships between variables. Difficulties in stoichiometry problem-solving are often associated with weak calculation skills, leading students to misinterpret molar ratios and reaction coefficients. According to [31], these difficulties arise from students' inability to integrate mathematical procedures with chemical concepts when quantitatively interpreting balanced equations. Furthermore, the inability to convert between units or correctly interpret numerical representations further reinforces these misconceptions.

d. Abstract and Symbolic Chemical Language

Chemical symbols, reaction equations, coefficients, and ideal gas notation are often considered complicated by students [32]. The inability to interpret chemical symbols and equations leads students to misunderstand the relationships between substances, such as assuming that coefficients only indicate the number of particles, rather than the ratio of gas volumes at STP. The unique and abstract language of chemistry causes misconceptions, especially among

students who are not yet familiar with it [33][34].

e. Lack of Motivation and Interest in Learning

Some students consider the material in Basic Chemistry to be calculation-based and difficult, which reduces their interest in learning. Low motivation causes students to pay less attention to explanations, practice fewer problems, and not try to understand concepts in depth [35]. This condition leads to undetected misconceptions that carry over to the next level of material [36].

Based on the results of an analysis of misconceptions among tenth-grade students at a public high school in Malang using a two-tier multiple-choice instrument, variations were found in the percentages of students who understood the concept (M), did not understand the concept (Mi), and had misconceptions. Overall, the average percentages for the categories of understanding the concept, misconception, and not understanding the concept reached 71%, 24%, and 5%, respectively. A more detailed description of the distribution of these categories is presented in Figure 1, Student Misconception Categories.

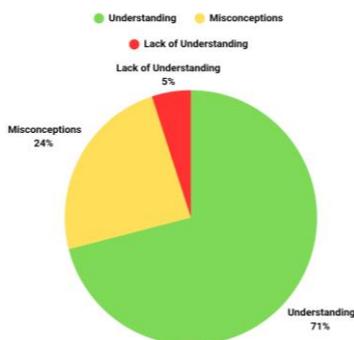


Figure 1. Diagram Showing the Overall Percentage of Students' Understanding of the Concept

Based on the image, there are three categories of student understanding: understanding the concept, misunderstanding, and not understanding the concept. There are still students who do not understand the material, and some others have misunderstandings about the concept. However, the percentage of students who understand the concept is much higher than the

percentage of students who have misunderstandings or do not understand the concept. The results of this study show that most students have understood the concepts that have been learned, although there are still a number of students who have misconceptions and a small number of students who do not yet understand the concepts properly. These results are in line with the results of research by [24] which concluded that even though there are students who fall into the category of understanding the concept, misconceptions are still found in basic chemistry material due to procedural rather than conceptual understanding. The study states that the abstract nature of the concept and its connection to mathematical reasoning are the main factors contributing to misconceptions among students.

Based on the results of this study, the chemistry learning process needs to be directed towards strengthening conceptual understanding through the application of multirepresentation-based learning strategies, the integration of mathematical concepts with chemical concepts, and the continuous use of diagnostic evaluations such as the Two-Tier Multiple Choice instrument. This approach is expected to help teachers identify students' misconceptions more accurately and prevent the continuation of misconceptions in subsequent chemistry lessons.

CONCLUSION

Based on the results of data analysis and discussion of students' misconceptions measured using a two-tier multiple-choice instrument, it can be concluded that 64% of Tenth-Grade students at a public senior high school in Malang exhibited misconceptions on the topic of Basic Chemistry Laws. The highest level of misconception was identified in item A15, which addressed the concept of Avogadro's Law.

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REFERENCES

1. Nasiwan, Wulandari, T., and Wijayanti, A. T. 2023. Integrating Democracy Learning and Prophetic Social Studies at Baitusalam Islamic School Yogyakarta. *Jurnal Civics Media Kajian Kewarganegaraan*, Vol. 20, No. 1, pp. 47–54.
2. Basir, M., Damopolii, M., and Yuspiyani, Y. 2024. Faktor-Faktor Determinan dalam Pendidikan. *JUPEIS: Jurnal Pendidikan dan Ilmu Sosial*, Vol. 3, No. 3, pp. 118–126.
3. Ridwan, R., Romadhona, H., and Sadewa, I. 2024. Analysis of the Factors Hindering the Improvement of Education Quality at SDN Lambangjaya 02 Tambun Selatan. *Greenation Education and Culture Review*, Vol. 1, No. 1, pp. 16–22.
4. Kumar, S. 2025. ‘Atoms Don’t Behave That Way!’ – Investigating Student Misconceptions in Stoichiometry and the Mole Concept. *Edumania-An International Multidisciplinary Journal*, Vol. 03, No. 03, pp. 216–239.
5. Elvia, R., Amelia, T., and Handayani, D. 2022. Identifikasi Miskonsepsi Siswa pada Pembelajaran Kimia Menggunakan Metode Four-Tier Diagnostik Test di SMA Negeri 03 Kota Bengkulu. *ALOTROP*, Vol. 6, No. 2, pp. 110–117.
6. Golestaneh, M., and Mousavi, S. M. 2024. Exploring Iranian Pre-Service Teachers Conceptual Understanding of Chemical Equilibrium. *Journal of Turkish Science Education*, Vol. 21, No. 1, pp. 110–117.
7. Zulkhairi. 2022. Studi Literatur: Analisis Miskonsepsi Siswa pada Topik Ikatan Kimia. *JURNAL Kajian Pendidikan IPA*, Vol. 2, No. 1, pp. 133–140.
8. Setiawan, N. C. E., and Ilahi, P. R. 2022. Identification of Misconceptions in Chemical Bonding Materials Using Three Tier Diagnostic Test. *Journal of Natural Science and Integration*, Vol. 5, No. 1, pp. 77.
9. Suryadi, A., and Husna, S. 2022. Asesmen Diagnostik Makro Persiapan Penerapan Kurikulum Merdeka MTsN 28 Jakarta. *JENTRE*, Vol. 3, No. 2, pp. 74–89.
10. Dendodi, D., Maria S, H. T., and Hamdani, H. 2020. Pengembangan Tes Diagnostik Four Tier Test Dilengkapi dengan Self-Diagnosis Sheet Tentang Energi di SMA. *Jurnal Inovasi Penelitian dan Pembelajaran Fisika*, Vol. 1, No. 1, pp. 8.
11. Wahyuningsih, E., and Maryani, I. 2023. Implementasi Asesmen Diagnostik dalam Meningkatkan Hasil Belajar Siswa SMP Negeri 1 Cicalongwetan. *Jurnal Manajemen Pendidikan Dasar, Menengah dan Tinggi [JMP-DMT]*, Vol. 4, No. 4, pp. 445–455
12. Pongkendek, J. J., and Kristiyasari, M. L. 2022. Penggunaan Two Tier Multiple Choice untuk Analisis Miskonsepsi Mahasiswa. *Quantum: Jurnal Inovasi Pendidikan Sains*, Vol. 13, No. 1, pp. 131.
13. Antari, W. D., Sumarni, W., Harjito, and Basuki, J. 2020. Model Instrumen Test Diagnostik Two Tiers Choice untuk Analisis Miskonsepsi Materi Larutan Penyangga. *DOAJ (DOAJ: Directory of Open Access Journals)*, Vol. 14, No. 1, pp. 2536–2546.
14. Treagust, D. F. 1988. Development and Use of Diagnostic Tests to Evaluate Students’ Misconceptions in Science. *International Journal of Science Education*, Vol. 10, No. 2, pp. 159–169.
15. Tüysüz, C. 2009. Development of Two-Tier Diagnostic Instrument and Assess Students’ Understanding in Chemistry. *Scientific Research and Essays*, Vol. 4, No. 6, pp. 626–631.
16. Sugiyono. 2008. *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, dan R&D)*. Bandung: Alfabeta.
17. Arikunto, S. 2021. *Dasar-Dasar Evaluasi Pendidikan Edisi 3*. Jakarta: Bumi Aksara.
18. Lahinda, C. G., and Tuerah, J. M. 2022. Analisis Miskonsepsi Siswa pada Materi Hukum Dasar Kimia Menggunakan Two-Tier Diagnostic Test di SMA Negeri 1 Tatapaan. *Oxygenius Journal of Chemistry Education*, Vol. 3, No. 1, pp. 35.
19. Nur, M. N., Astutik, T. P., and Oktapianti, S. 2024. Misconception on Stoichiometric Material in Students Using the Four-Tier Diagnostic Test. *Nukleo Sains: Jurnal Pendidikan IPA*, Vol. 3, No. 1, pp. 41–49.

20. Edelsztein, V. C. 2023. An Experimental Approach with a Twist: Helping High School Students to Understand the Concept of Limiting Reactant. *Journal of Chemical Education*, Vol. 100, No. 4.
21. Sihaloho, T., Sidauruk, S., and Anggraeni, M. E. 2024. Analisis Kesulitan Siswa dalam Memahami Konsep Hukum-Hukum Dasar Kimia (Systematic Review). *Jurnal Ilmiah Kanderang Tingang*, Vol. 15, No. 2, pp. 451–463.
22. Putri, V. L., and Dj, L. 2022. Description of Students Learning Difficulties in the Basic Law of Chemistry. *Jurnal Pijar Mipa*, Vol. 17, No. 5, pp. 597–603.
23. Chang, R., and Goldsby, K. A. 2016. *Chemistry, 12th ed.* New York: Mcgraw-Hill Education.
24. Suparman, A. R., Rohaeti, E., and Wening, S. 2024. Student Misconception In Chemistry: A Systematic Literature Review. *Pegem Journal of Education and Instruction*, Vol. 14, No. 2, pp. 238–252.
25. Sari, D. N., Nurhamidah, and Wiwit. 2024. Analisis Miskonsepsi Siswa pada Materi Stoikiometri Menggunakan Test Diagnostic Essay Berbantuan CRI. *ALOTROP*, Vol. 8, No. 2, pp. 32–45.
26. Johnstone, A. H. 1991. Why is Science Difficult To Learn? Things are Seldom What They Seem. *Journal of Computer Assisted Learning*, Vol. 7, No. 2, pp. 75–83.
27. Chandrasegaran, A. L., Treagust, D. F., and Mocerino, M. 2007. An Evaluation of a Teaching Intervention to Promote Students' Ability to Use Multiple Levels of Representation When Describing and Explaining Chemical Reactions. *Research in Science Education*, Vol. 38, No. 2, pp. 237–248.
28. Taber, K. S. 2017. The Nature of Student Conceptions in Science. *Science Education*, pp. 119–131.
29. Arsani, I. A. A., Setyosari, P., Kuswandi, D., and Dasna, I. W. 2020. Problem-Based Learning Strategies Using Multiple Representations and Learning Styles to Enhance Conceptual Understandings of Chemistry. *Periódico Tchê Química*, Vol. 17, No. 35, pp. 860–876.
30. DeDecker, S., Chouvalova, A., Gordon, K., Clemmer, R., and Vale, J. 2022. Memorization: Friend or Foe when Solving Problems in STEM Undergraduate Courses. *Proceedings 2022 Canadian Engineering Education Association (CEEA-ACEG22) Conference*.
31. Shadreck, M., and Ochonogor, C. E. 2018. Recurrent Difficulties: Stoichiometry Problem-Solving. *African Journal of Educational Studies in Mathematics and Sciences*, Vol. 14, pp. 25–31.
32. Taber, K. S. 2019. Conceptual Confusion in the Chemistry Curriculum: Exemplifying the Problematic Nature of Representing Chemical Concepts as Target Knowledge. *Foundations of Chemistry*, Vol. 22, No. 2, pp. 309–334.
33. Chandrasegaran, A. L., Treagust, D. F., Mocerino, M., Won, M., and Karpudewan, K. 2016. Investigating High School Students' Understanding of Chemical Equilibrium Concepts. *The International Journal of Environmental and Science Education*.
34. Aini, R. G., Ibnu, S., and Budiasih, E. 2016. *Identifikasi Miskonsepsi dalam Materi Stoikiometri pada Siswa Kelas X di SMAN 1 Malang melalui Soal Diagnostik Three-Tier*. Malang: Universitas Negeri Malang.
35. Priliyanti, A., Muderawan, I. W., and Maryam, S. 2021. Analisis Kesulitan Belajar Siswa dalam Mempelajari Kimia Kelas XI. *Jurnal Pendidikan Kimia Undiksha*, Vol. 5, No. 1, pp. 11.
36. Pahriah, P., Sudatha, I. G. W., Suartama, I. K., and Santosa, M. H. 2025. Students' Misconceptions in Chemistry Learning: A Systematic Literature Review from 2015 to 2025. *Hydrogen: Jurnal Kependidikan Kimia*, Vol. 13, No. 3, pp. 510–529.