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IDENTIFYING STUDENTS' MISCONCEPTIONS IN CHEMICAL EQUILIBRIUM MATERIAL USING A FIVE-TIER MULTIPLE CHOICE DIAGNOSTIC TEST

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Abstract

This study aims to identify the profile of students' misconceptions on chemical equilibrium and to determine the sources of these misconceptions. This study used a descriptive method with quantitative and qualitative approaches and was conducted at SMA Negeri 7 Pekanbaru. The research subjects involved 187 11th-grade students who had studied chemical equilibrium. Data collection was conducted using a five-level diagnostic test instrument consisting of 15 questions and structured interviews. Data were analyzed quantitatively by calculating the percentage of students in each misconception category and interpreting the results descriptively. Qualitative interview data were analyzed through data reduction, data display, and conclusion drawing to identify the sources of misconceptions. The results showed that the average percentage of students experiencing misconceptions was relatively low, at 20.93%. Analysis of the sources of misconceptions showed that the main cause of misconceptions came from students' personal thoughts, with a percentage of 24.15%. Other contributing sources included friends (20.66%), teachers (18.78%), the internet (18.35%), and books (18.06%). These findings indicate that students' misconceptions are more influenced by independent constructions of understanding that do not align with scientific concepts than other external factors.

Keywords: Chemical Equilibrium, Five Diagnostic Tests, Misconceptions

INTRODUCTION

Understanding chemical concepts is fundamental in chemistry learning because these concepts are interconnected and hierarchical. Misunderstanding a basic concept can lead to errors in subsequent concepts (Jere & Mpeta, 2024), which ultimately give rise to misconceptions due to incorrect understanding. Misconceptions experienced by students can result in low learning outcomes and academic achievement. One topic of chemistry that is prone to misconceptions is chemical equilibrium (Mukhlisa, 2021). This material is complex and abstract in nature, requiring the active involvement of students in the learning process so that the concepts can be understood correctly (Indriani & Suryadharma, 2017). Misconceptions in chemical equilibrium material also have the potential to affect students' understanding of other related chemistry materials, such as stoichiometry and electrochemistry, given the interrelationship between concepts in chemistry.

Previous studies (state of the art) have documented that common misconceptions in chemical equilibrium involve misunderstandings of reaction rates, equilibrium constants, and factors affecting equilibrium shifts such as changes in concentration, temperature, and pressure (Mayasri et al., 2023). Students often experience confusion in understanding the relationship between equilibrium constants and reaction rates, as well as in determining the effect of changes in conditions on the equilibrium position (Arikunto, 2010). In addition, students also often have difficulty distinguishing between reactions that have reached equilibrium and those that have not (Sugiarti & Sukarmin, 2019). These findings indicate that misconceptions in

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chemical equilibrium remain a persistent issue that requires accurate diagnostic identification.

Preliminary observations as a research background through interviews with a chemistry teacher at SMAN 7 Pekanbaru revealed that student achievement in chemical equilibrium is still relatively low. The average daily test scores for 11th grade students are in the range of 62–65, which is still below the minimum passing score of 75. Although some students are able to complete the questions up to the final stage, conceptual errors are still frequently found, such as the assumption that the reaction stops when equilibrium is reached, that catalysts can shift the position of equilibrium, and errors in interpreting the factors that affect the equilibrium constant. This condition suggests the presence of underlying misconceptions that may hinder students' mastery of subsequent chemistry topics.

Identifying students' misconceptions can be done through various methods, such as the Certainty of Response Index (CRI) and tiered diagnostic tests, ranging from two-tier to five-tier multiple choice. However, CRI has limitations because it cannot reveal the reasons behind students' answers. The development of diagnostic instruments shows that five-tier multiple-choice tests have advantages in identifying misconceptions more deeply, because they not only measure answers and confidence levels, but also the reasons and sources of information used by students (Danar et al., 2024; Erwinsyah et al., 2020; Tika et al., 2023). Thus, this instrument is considered more effective and comprehensive in revealing students' misconception profiles.

Previous studies have shown the effectiveness of five-tier multiple choice diagnostic tests in identifying students' misconceptions on various chemistry topics. Danar et al. (2024) found that most students had partial understanding with misconceptions influenced by personal thinking, while Lestari (2012) reported that the sources of students' misconceptions came from various factors, such as their own thinking, friends, teachers, books, and the internet.

Despite prior research, several gaps remain. Previous studies have largely focused on topics such as acids–bases, stoichiometry, or chemical bonding, with limited investigation of chemical equilibrium at the senior high school level. Furthermore, few studies have simultaneously examined misconception types, confidence levels, reasoning consistency, and sources of misconceptions using a five-tier diagnostic framework.

Accordingly, this study offers novelty by applying a five-tier multiple-choice diagnostic test to systematically analyze students' misconceptions on chemical equilibrium among class XI MIPA students at SMAN 7 Pekanbaru. The study integrates analysis of conceptual understanding, reasoning patterns, confidence levels, and sources of misconceptions within a single diagnostic framework. This comprehensive approach is expected to provide deeper insight into the complexity of students' misconceptions and to generate empirical evidence for developing more targeted instructional and remedial strategies in chemistry education.

METHODS

This study uses a descriptive method with a quantitative and qualitative approach. The descriptive method was chosen because this study did not aim to test hypotheses but rather to systematically and accurately describe the profile of students' misconceptions on chemical equilibrium material (Arikunto, 2010). The quantitative approach was used to calculate the percentage of students' misconceptions, while the qualitative approach was used to reveal the sources of these misconceptions.

The study was conducted at SMAN 7 Pekanbaru on grade XI MIPA students in the 2025/2026 academic year, with data collection in December 2025. The population in this study was all grade XI students at SMAN 7 Pekanbaru who had studied chemical equilibrium material. The research sample consisted of 187 students, comprising 105 female students and 82 male students, who were selected because they had received instruction on chemical equilibrium material from the same subject teacher.

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Data collection was conducted through tests and interviews. The test instrument used was a five-tier multiple-choice diagnostic test, which aimed to identify students' misconceptions and their causes. This instrument consisted of five levels, namely multiple-choice answers, level of confidence in the answers, reasons for choosing the answers, level of confidence in the reasons, and sources of information used by students in answering the questions. The five-tier diagnostic test is considered to provide a more comprehensive picture of students' understanding and misconceptions compared to other multi-level diagnostic instruments (Danar et al., 2024).

The diagnostic test used consisted of 15 items adapted from Akbar (2017), Damayanti (2025), and Azizah (2023). The instrument, which was originally a four-tier form, was modified into a five-tier form with the addition of information source identification. All items have undergone a validation process and are classified as excellent, and their validity and reliability were retested before being used in the study.

In addition to tests, structured interviews were conducted as supporting data to deepen the analysis of the causes of students' misconceptions. Interview subjects were selected using purposive sampling techniques, namely students who were identified as having misconceptions based on the results of diagnostic tests. Interviews were conducted to obtain information related to the reasons and sources of understanding behind the students' answers.

Data analysis was carried out by grouping students' responses based on the combination of answers and confidence levels from the first to the fourth tiers to determine the categories of correct understanding, lack of understanding, and misconceptions. The fifth tier was used to identify the sources of misconceptions, including books, teachers, friends, the internet, and personal thoughts. The percentage of misconceptions was calculated using the following formula:

$$\boldsymbol{P} = \frac{\boldsymbol{f}}{\boldsymbol{N}} \times \mathbf{100\%}$$

where $\boldsymbol{P}$ is the percentage of students in each category, $\boldsymbol{f}$ is the number of students in the category, and $\boldsymbol{N}$ is the total number of students. The obtained percentages were then categorized into low, medium, and high levels as presented in Table 1 (Suwardika et al., 2024). The interview data were analyzed qualitatively to reinforce and explain the quantitative findings related to the sources of students' misconceptions.

Table 1. Misconception Criteria Based on Percentage

Category	Percentage
High	61%-100%
Medium	31%-60%
Low	0%-30%

RESULTS AND DISCUSSION

This study used a five-tier diagnostic test to identify students' level of understanding of chemical equilibrium concepts. Based on the data processing results of 187 students, it was found that the average percentage of students with misconceptions was 20.93%, which was categorized as low (0%–30%). Overall, the distribution of students' level of understanding is presented in the following categories (Figure 1): no understanding of the concept (29.38%), understanding of the concept (20.92%), misconception (20.93%), false positive (18.65%), and false negative (10.12%). Details of misconceptions based on sub-material can be seen in Table 2.

Table 2. Percentage of Misconceptions Among Students per Sub-Topic

Main Material Description	Question Item	Percentage of Misconceptions	Category
Basic Concepts of Equilibrium	1	19,25	Low
	2	19,25	
	3	25,67	
Calculation of Kc and Kp	4	16,58	Low
	5	33,16	
	6	35,29	
Factors Affecting Equilibrium	7	11,77	Low
	8	17,11	
	9	13,90	
	10	18,72	
	11	17,11	
	12	28,34	Low

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Main Material Description	Question Item	Percentage of Misconceptions	Category
Application of the concept of equilibrium in life	13 14 15	25,67 13,90 18,18	

The relatively low percentage of misconceptions indicates that many students have begun to develop scientifically acceptable conceptions of chemical equilibrium, although their understanding is not yet fully robust. One plausible explanation is that equilibrium is a topic that is repeatedly practiced through algorithmic exercises in high school chemistry, which can reduce the surface appearance of misconceptions even when conceptual understanding remains partial (Chang, 2005; Indriani & Suryadharma, 2017). This condition is consistent with the view that students may arrive at correct answers procedurally without fully restructuring their conceptual frameworks (Bodner, 1986; Taber, 2003).

In addition, the use of a five-tier diagnostic instrument applies stricter criteria for identifying misconceptions because students must simultaneously demonstrate incorrect answers, high confidence, and consistent reasoning. Multi-tier diagnostics are known to filter out weak or uncertain misconceptions and more accurately detect strongly held alternative conceptions (Caleon & Subramaniam, 2010; Danar et al., 2024; Muzakki et al., 2023; Tyson et al., 1999). Therefore, the low misconception percentage in this study should be interpreted carefully not as the absence of conceptual problems, but as an indication that misconceptions exist alongside other response patterns such as lack of understanding and false positives.

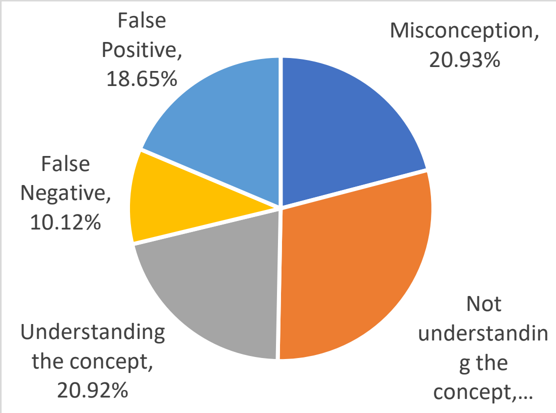

Figure 1. Categories of Student Understanding

Based on the results of the five-tier multiple-choice diagnostic test presented in Table 2, grade XI MIPA students at SMAN 7 Pekanbaru still have misconceptions about all indicators of chemical equilibrium material, including basic concepts, equilibrium calculations, equilibrium shifts, and the application of equilibrium concepts. The distribution of answer categories shows that misconceptions appear with varying percentages for each indicator but are still in the low category. These misconceptions are characterized by answers that are not in accordance with scientific concepts but are accompanied by a high level of confidence, indicating the strength of the alternative understanding possessed by the students.

In the basic concept of chemical equilibrium indicator (questions 1–3), as shown in Table 2, some students still have misconceptions about the nature of chemical equilibrium. This misconception reflects a well-documented tendency to interpret equilibrium as a static condition rather than a dynamic process occurring at equal forward and reverse reaction rates (Jere & Mpeta, 2024; Kang & Wallace, 2005). Students tend to assume that chemical reactions stop when they reach equilibrium. The percentage of misconceptions on this indicator shows that students' understanding of the dynamic nature of chemical equilibrium is still not optimal. This finding is in line with Jere & Mpeta (2024), who stated that misconceptions about equilibrium as a static condition are common conceptual errors. The high level of

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confidence of students in incorrect answers indicates that an inaccurate intuitive understanding has been formed and has not been conceptually corrected (Suparno, 2013).

In the chemical equilibrium calculation indicators (questions 4–6), the results in Table 2 show misconceptions related to the use of equilibrium constants (Kc). Students tend to use formulas directly without understanding the chemical meaning of the quantities being calculated. The percentage of misconceptions on this indicator shows that a procedural approach still dominates students' thinking in solving problems. Chang (2005) asserts that the separation between mathematical processes and conceptual understanding is one of the main causes of errors in equilibrium material. This is reinforced by Indriani & Suryadharma (2017), who state that the use of formulas without conceptual understanding can reinforce students' misconceptions.

The misconception with the highest relative percentage was found in the equilibrium shift indicator (questions 7–11) as shown in Table 2. Students had difficulty determining the direction of equilibrium shift due to changes in concentration, temperature, and pressure. The high percentage of misconceptions on this indicator shows that students tend to memorize Le Chatelier's principle without understanding the cause-and-effect relationship in equilibrium systems. This finding is in line with Mayasri et al. (2023), who stated that misconceptions about equilibrium shifts arise from the mechanical application of rules. According to Suparno (2013), misconceptions accompanied by high confidence are classified as strong misconceptions that are difficult to correct without a conceptual change strategy.

In the indicator of the application of the concept of chemical equilibrium (questions 12–15), based on Table 2, students' misconceptions were related to errors in identifying the type of system and the nature of equilibrium reactions. The percentage of misconceptions in this indicator shows that students are not yet able to integrate the basic concepts of equilibrium with the applied context. Students tend to simplify the concept by assuming that all reactions are homogeneous and can occur in both directions. Lestari (2022) states that misconceptions at the concept application stage are a continuation of incomplete understanding of basic concepts, while Mukhlisa (2021) emphasizes that errors in chemical equilibrium material have the potential to affect understanding of advanced chemistry material.

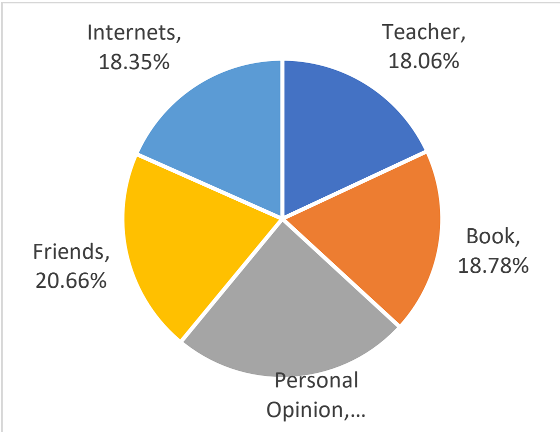

Figure 2. Percentage of Sources of Misconceptions

The analysis of the sources of misconceptions was conducted after the analysis of misconceptions from 15 questions had been completed. The results of this analysis of the sources of misconceptions can be seen in Figure 2. Based on the results of the analysis of the sources of misconceptions presented in Figure 2, it is known that the students' misconceptions originated from personal thoughts, books, teachers, friends, and the internet, with personal thoughts being the most dominant source (24,15%).

The dominance of personal thoughts can be explained through the constructivist perspective, which emphasizes that learners actively construct knowledge based on prior conceptions and everyday experiences (Bodner, 1986; Taber, 2003). When these initial ideas are not explicitly challenged during instruction, they tend to persist as stable misconceptions (Novak & Treagust, 2018; Suparno, 2013).

Chemical equilibrium concepts are abstract and often counterintuitive; therefore, students frequently rely on everyday reasoning (e.g., “reactions stop at equilibrium”) to interpret the phenomenon. Research has shown that such

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intuitive reasoning strongly contributes to internally generated misconceptions (Barke et al., 2009; Kang & Wallace, 2005). This finding is in line with Erwinsyah et al. (2020) and Lestari (2022), who stated that personal thoughts become the main source of misconceptions if they are not systematically identified and clarified in learning. In addition, learning resources and material delivery that do not emphasize concept clarification also contribute to the reinforcement of misconceptions experienced by students.

Another explanation for the higher percentage of personal thought (24,15%) compared to external sources is that learning materials and teacher explanations may already present scientifically correct information, thereby reducing their direct contribution to misconceptions. In such contexts, misconceptions more often arise from students' misinterpretation, oversimplification, or incomplete integration of correct information (Caleon & Subramaniam, 2010; Tyson et al., 1999).

Furthermore, cognitive factors such as overconfidence and belief perseverance can cause students to maintain their self-generated explanations even when confronted with correct information. Without instructional strategies that explicitly promote conceptual change, these internally constructed ideas tend to remain dominant (Arslan et al., 2023; Taber, 2003).

Overall, the synchronization between the results in Table 2 and Figure 2 shows that students' misconceptions about chemical equilibrium are comprehensive, covering conceptual, procedural, and applicative aspects. The five-tier multiple-choice diagnostic test instrument proved to be effective in identifying patterns of misconceptions and their sources comprehensively. Therefore, chemical equilibrium learning needs to be directed at strengthening conceptual understanding and exploring students' initial conceptions so that misconceptions can be minimized continuously (Danar et al., 2024).

CONCLUSION

Research conducted at SMA Negeri 7 Pekanbaru shows that grade XI students have misconceptions about chemical equilibrium material with an average percentage of 20.93% (low category), where the highest level of misconception was found in the sub-material of Kc and Kp calculations (28.34%) due to the dominance of algorithmic thinking rather than conceptual understanding. These findings confirm that misconceptions are spread across all indicators, from basic concepts to real-life applications, triggered by five main sources, with the most dominant contribution coming from the students' own personal thinking (24.15%). Although quantitatively the percentage of misconceptions is relatively low, the pattern of errors that occur is fundamental because students tend to develop independent intuitions that are not in line with scientific concepts. This implies the need for teachers to conduct diagnostic assessments at the beginning of learning and provide special reinforcement on the submicroscopic aspects and interrelationships between concepts to minimize misunderstandings on an ongoing basis.

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REFERENCES

Akbar, Z. D. (2017). *Identifikasi Miskonsepsi Materi Kesetimbangan Kimia Menggunakan Tes Diagnostik Pilihan Ganda Tiga Tingkat (Three-Tier Multiple Choice) Pada Peserta Didik Kelas XI MIA SMA Negeri 2 Pekanbaru*. Universitas Riau.

Arikunto. (2010). *Prosedur Penelitian, Suatu Studi Pendekatan Praktek*. Rineka Cipta.

Jurnal Zarah
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p-ISSN: 2354-7162 | e-ISSN: 2549-2217
Available online at https://ojs.umrah.ac.id/index.php/zarah/index
DOI: 10.31629/zarah.v14i1.8138

Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. *Teaching and Teacher Education*, *121*. https://doi.org/10.1016/j.tate.2022.103905

Azizah, V. N. (2023). *Identifikasi Miskonsepsi Peserta Didik Menggunakan Tes Diagnostik Five-Tier Multiple Choice Pada Materi Reaksi Redoks Kelas X Di SMAN 1 Pangkalan Kerinci*. Universitas Riau.

Barke, H.-D., Hazari, A., & Yitbarek, S. (2009). *Misconceptions in Chemistry*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-70989-3

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63*(10), 873. https://doi.org/10.1021/ed063p873

Caleon, I. S., & Subramaniam, R. (2010). Do Students Know What They Know and What They Don't Know? Using a Four-Tier Diagnostic Test to Assess the Nature of Students' Alternative Conceptions. *Research in Science Education*, *40*(3), 313–337. https://doi.org/10.1007/s11165-009-9122-4

Chang, R. (2005). *Kimia Dasar Konsep-Konsep Inti Edisi Ketiga Jilid 2*. Erlangga.

Damayanti, T. (2025). *Analisis Kemampuan Berpikir Kritis Siswa Menggunakan Tes Diagnostik Four-Tier Pada Materi Kesetimbangan Kimia*. Universitas Negeri Islam Sultan Syarif Kasim.

Danar, S., Sari, C., Ardi, T., Parameswary, C. S., & Widiastuti, N. L. (2024). Identifying Students' Understanding Levels And Sources Of Misconceptions In Acid-Base Concepts Through A Five-Tier Diagnostic Test. *Jurnal Kimia Dan Pendidikan*, *10*(1), 163–174. https://doi.org/10.62870/educhemia.v10i1.35563

Erwinsyah, H., Muhassin, M., & Asyhari, A. (2020). Pengembangan four-tier diagnostic test untuk mengetahui pemahaman konsep peserta didik pada materi gerak lurus. *Jurnal Pendidikan Fisika Dan Keilmuan (JPFK)*, *6*(1), 1. https://doi.org/10.25273/jpfk.v6i1.5125

Indriani, A., & Suryadharma, I. B. (2017). Identifikasi Kesulitan Peserta Didik dalam Memahami Kesetimbangan Kimia. *Jurnal Pembelajaran Kimia*, *2*(1), 9–13.

Jere, S., & Mpeta, M. (2024). Enhancing Learners' Conceptual Understanding of Reaction Kinetics Using Computer Simulations – A Case Study Approach. *Research in Science Education*, *54*(6), 999–1023. https://doi.org/10.1007/s11165-024-10182-5

Kang, N.-H., & Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education*, *89*(1), 140–165. https://doi.org/10.1002/sce.20013

Lestari. (2012). Pengaruh Model Pembelajaran Berbasis Masalah (Problem- Based Learning) dan Motivasi Belajar terhadap Prestasi Belajar Fisika bagi Siswa Kelas VII SMP. *Jurnal Teknologi Pembelajaran Indonesia*, *1*(2), 1–21.

Lestari, A. (2022). *Identifikasi Miskonsepsi Siswa Kelas XI di SMAN 1 Tulung Agung pada Materi Laju Reaksi dengan Menggunakan Instrumen Lima tingkat Diagnostic Test*. UIN Satu Tulung Agung.

Mayasri, A., Reza, M., & Nasir, D. M. (2023). Identifikasi dan Remediasi Miskonsepsi dengan Pendekatan Perubahan Konseptual pada Materi Kesetimbangan Kimia. *Orbital: Jurnal Pendidikan Kimia*, *7*(2).

Mukhlisa, N. (2021). Miskonsepsi Pada Peserta Didik. *SPEED Journal : Journal of Special Education*, *4*(2), 66–76. https://doi.org/10.31537/speed.v4i2.403

Muzakki, N. A., Diana, S., & Priyandoko, D. (2023). Misconception Analysis of Cell Material Using Four-Tier Multiple Choice Diagnostic Test. *Quagga: Jurnal Pendidikan Dan Biologi*, *15*(2), 120–130. https://doi.org/10.25134/quagga.v15i2.32

Novak, A. M., & Treagust, D. F. (2018). Adjusting claims as new evidence emerges:

p-ISSN: 2354-7162 | e-ISSN: 2549-2217
Available online at https://ojs.umrah.ac.id/index.php/zarah/index
DOI: 10.31629/zarah.v14i1.8138

Do students incorporate new evidence into their scientific explanations? *Journal of Research in Science Teaching*, *55*(4), 526–549. https://doi.org/10.1002/tea.21429

Sugiarti, F., & Sukarmin. (2019). Mendeteksi dan Mereduksi Miskonsepsi dengan menggunakanSoftware Dered Misequilibri Pada Materi Kesetimbangan Kimia. *Unesa Journal of Chemical Education*, *8*(1), 94–100.

Suparno, P. (2013). *Miskonsepsi & Perubahan Konsep dalam Pendidikan Fisika*. Grasindo.

Suwardika, G., Sopandi, A. T., Indrawan, I. P. O., & Masakazu, K. (2024). A flipped classroom with whiteboard animation and modules to enhance students' self-regulation, critical thinking and communication skills: a conceptual framework and its implementation. *Asian Association of Open Universities Journal*, *19*(2), 135–152. https://doi.org/10.1108/AAOUJ-10-2023-0115

Taber, K. S. (2003). The Atom in the Chemistry Curriculum: Fundamental Concept, Teaching Model or Epistemological Obstacle? *Foundations of Chemistry*, *5*(1), 43–84. https://doi.org/10.1023/A:1021995612705

Tika, P. N., Jariah, Y. A., Melina, M. M., Ristanto, R. H., & Isfaeni, H. (2023). Pengembangan Instrumen Tes Diagnostik Three-Tier Pada Pembelajaran Sistem Ekskresi Berdiferensiasi. *Bio-Lectura : Jurnal Pendidikan Biologi*, *10*(2), 167–182. https://doi.org/10.31849/bl.v10i2.14610

Tyson, L., Treagust, D. F., & Bucat, R. B. (1999). The Complexity of Teaching and Learning Chemical Equilibrium. *Journal of Chemical Education*, *76*(4), 554. https://doi.org/10.1021/ed076p554