ORBITAL: JURNAL PENDIDIKAN KIMIA
Website : jurnal.radenfatah.ac.id/index.php/orbital
ISSN 2580-1856 (print) ISSN 2598-0858 (online)

Identification of Misconceptions and Causes of Misconceptions in Stoichiometry Material Using Four Tier Multiple Choice (4TMC)

Dyah Ashfarini [1] and Setia Rahmawan [2*)]

[1,2]UIN Sunan Kalijaga, Yogyakarta, Indonesia

[*)]E-mail: setia.rahmawan@uin-suka.ac.id

ARTICLE INFO

Article History:
Received January 2024
Revised May 2024
Accepted June 2024
Published June 2024

Keywords:
Four tier multiple choice;
Misconceptions;
Stoichiometric;

ABSTRACT

Stoichiometry is one of the materials in chemistry in high school that contains basic concepts for understanding other chemistry. Some students need help to understand and even experience misconceptions. This research aims to identify subconcepts that experience misconceptions, the percentage of students who experience misconceptions, and the causes of misconceptions. The research method used is a quantitative descriptive method. The sample for this research was students of class X MIPA at one of the schools in Yogyakarta, taken based on a purposive sampling technique. The research instrument used was the Four Tier Multiple Choice (4TMC) diagnostic test instrument. Answer patterns, reasons, and self-confidence assessments from the 4TMC test results were then processed and analyzed to obtain significant misconception data from students. The research results are misconceptions in the stoichiometry material, especially in the sub-concepts of Avogadro's Hypothesis, Proust's Law, Dalton's Law, Ar and Mr, the percentage of class X students in the stoichiometry material who experience misconceptions is 25.35% are classified as low, and the causes of misconceptions experienced by class X students regarding Stoichiometry material come from teachers, students, and books. Misconceptions originating from teachers relate to methods, techniques, and delivery of learning. Misconceptions originating from students are caused by students' wrong conceptions, dependent algorithmic phenomena, students' abilities, and interests, which need to be improved. A misunderstanding of the book is the presence of inappropriate concepts in students' notebooks. Identifying these misconceptions is expected to be the first step in resolving students' misconceptions about stoichiometry and preventing persistent misconceptions.

INTRODUCTION

The subject of chemistry became a fundamental field of study. This is because almost everything in life can be explained through aspects of chemistry. Speaking of chemistry, chemistry is divided into three significant aspects. Macroscopic, microscopic, as well as symbolic aspects. According to the Ministry of National Education (2006), chemistry studies various knowledge in theories, concepts, principles, rules, facts, descriptions, chemical terms, and the discovery process. These concepts are arranged starting from the simplest to the most complex. The level of concepts in chemistry is arranged based on matter, the complexity of matter, and the level of difficulty of matter. According to Tsarpalis et al. (Winarni, 2016), this concept in chemistry is hierarchical. So, it is essential to understand matter according to the hierarchy and the relationship between concepts in chemistry.

Understanding chemistry is essential. Besides being used in everyday logic, chemistry is also a prerequisite for assessing chemistry subjects in high school or high school. So, understanding chemistry in schools is a fundamental step that students must take. The ability to understand chemistry subjects means more than just memorizing formulas or theories. The learning outcomes obtained from memorization will become a temporary understanding (Sariati et al., 2020) and will cause less meaningful learning (Bunyamin, 2021; Sariati et al., 2020). In addition, from memorizing alone, learners will find it challenging to solve varied cases. Therefore, it is necessary to understand chemistry subjects by knowing the causes, effects, and correlations of subconcepts in chemistry to achieve meaningful learning.

The reality that occurs in the process of transferring chemistry in high school is that there are still many students who do not master concepts in chemistry. Based on a preliminary interview with a chemistry teacher in class X of SMA N 1 Jetis, the results of studying chemistry in class X of SMA N 1 Jetis are still below KKM, which is 65. This low learning outcome indicates that learners have learning difficulties. Learning difficulties can be caused by misconceptions about the material in chemistry subjects, resulting in the concepts owned by students needing to be more meaningful and able to connect with other concepts (Nursiwin, 2014). The phenomenon of misconceptions in learners often occurs in stoichiometric material.

Research on chemical misconceptions on stoichiometric subject matter has been conducted by Zidny, Sopandi, and Kusrijadi (Zidny et al., 2013) on grade X students at SMA Negeri Bandung, where the results showed that almost 50% of the samples studied experienced misconceptions. Similar research was also conducted by Aini et al., (2016), where misconceptions about stoichiometry material also occurred in grade X students of SMA N 1 Malang. Therefore, it is necessary to identify misconceptions in students, especially in stoichiometric material, because it is the core material and the basis of other chemical materials (Ernawati et al., 2015). In addition, the identification of misconceptions will later be used as material to evaluate the chemistry learning process.

The methods used to identify misconceptions vary widely, such as through interviews and diagnostic tests. According to Sudijono (Zafitri et al., 2018), the interview method is effective if the number of students is small and the answers are general, making identifying misconceptions less accurate. Therefore, the method that is considered suitable and accurate is to use diagnostic tests. According to Treagust (Zafitri et al., 2018), diagnostic tests do not take long and can provide an accurate picture of misconceptions experienced by students. One example of a diagnostic test to identify misconceptions is the Four Tier Multiple Choice (4TMC). This instrument has advantages over other diagnostic test methods, namely that a confidence rating gives a picture of students' confidence in answer choices and choice of reasons (Islami et al., 2018; Karim, 2020; Rusilowati, 2015).

METHODS

Research Design

This study used a quantitative descriptive research method. Quantitative descriptive research is used to systematically, accurately, and factually describe the facts and properties of a particular population or describe a phenomenon in detail (Yusuf, 2016). Quantitative descriptive research in this study aims to identify and then describe what misconceptions occur in students, the percentage of students who experience misconceptions, and the causes of misconceptions that occur.

In this study, the scope of the research object studied is subconcepts that experience misconceptions, many misconceptions of stoichiometric material, and the causes of misconceptions.

The research procedure begins with the preparatory stage. In the preparation stage, the steps taken are determining samples with teachers in the field of study, analyzing the score of chemistry subjects, preparing four-tier multiple-choice instruments, making open-ended questions, conducting expert validation, instrument trials, and reliability tests. The next stage is the data collection stage. Four-tier multiple-choice instruments were disseminated at the data collection stage, interviews of students and teachers supporting the field of study, and documentation studies were carried out. Then, the data obtained is carried out in the data processing stage. The data processing stage is by analyzing the data results from the four-tier multiple choice instrument by categorizing student answer patterns based on the level of student understanding, analyzing the results of interviews with students and teachers in the field of study, the results of documentation studies to strengthen the reasons for causing misconceptions and drawing conclusions on existing problem formulations.

Research Target

The population in this study was grade X students at SMA Negeri 1 Jetis. In this study, the sampling technique used was nonprobability sampling with purposive sampling techniques. The reason for using the purposive sampling technique is that not all samples have criteria that are by the phenomenon under study and to minimize other variables that can affect the study

Research Data

The data collected in this study are the results of test instrument.

Research Instruments

The research instrument used in this study is the Four Tier Multiple Choice (4TMC) test instrument, which is adjusted to the essential competencies used. The Four Tier Multiple Choice (4TMC) test instrument used is a development of the theory of Caleon and Subramaniam (Caleon & Subramaniam, 2010), Gurel et al. (Gurel et al., 2015), and Ismail et al. (Ismail et al., 2015). This instrument modifies the two-tier test instrument by adding confidence tiers to each tier of answers and reasons as the second and fourth tiers. According to Table 1. of the Student Confidence Rating Scale, this instrument uses a confidence rating scale.

Table 1. Student Confidence Rating Scale

Confidence Rating Scale	Scale Criteria
1	Just Guessing
2	Very Unconfident
3	Unconfident
4	Confident
5	Very Confident
6	Confident

Data Analysis

The four-tier multiple choice instrument is tested for validity, reliability, differentiation power test, and difficulty level on each question item. Test validity using Pearson's product-moment correlation coefficient method. At the same time, the reliability test in this study used Cronbach's Alpha.

The four-tier multiple choice instrument test result data is analyzed based on answer patterns, reasons, and confidence ratings selected by students to subsequently determine the description of student understanding categories based on Table 2. Student’s Answer Patterns and Reasons.

Table 2. Student’s Answer Patterns and Reasons.

Category	Tier 1	Tier 2	Tier 3	Tier 4
M	Correct Wrong	1 – 6	Wrong	≥ 4
L	Correct	1 – 6	Correct Wrong	≤ 3
	Correct	≤ 3	Correct	≤ 4
	Wrong	1 – 6	Correct Wrong	≤ 3
E	Wrong	1 – 6	Correct	≥ 4
P	Correct	≥ 4	Correct	≥ 4

Descriptions: Confidence Rating (CR), Misconception (M), Lack of Knowledge (L), Mistake (E), and Understand the Concept (P).

Furthermore, the category of students' understanding is calculated as a percentage to determine the level of misconception category that occurs. The misconception category is low if the percentage is <30%, moderate misconception if the percentage is large 31%-60%, and misconception is high if the percentage is >61%. Misconceptions that occur in students are then reprocessed to determine significant misconceptions. The determination of significant misconceptions aims to avoid learners' answers that are coincidental. Misconceptions are said to be significant if answer choices and reasoning are found to be at least ≥10% of the number of learners.

Significant misconceptions can be grouped into genuine and false misconceptions based on the average Confidence Rating score. If a significant misconception has an average Confidence Rating score of <3.50 or falls into a weak level, then a significant misconception is said to be false. Meanwhile, if a significant misconception has an average Confidence Rating score of > 3.50 or belongs to the middle or strong level, then the misconception is said to be a genuine misconception.

RESULTS AND DISCUSSION

The instrument has gone through a validity test calculation based on the results of the researcher's trials using SPSS version 24 with the Pearson Product Moment correlation coefficient method used to test the validity, resulting in 21 questions out of 31 questions being declared valid. The validated four-tier multiple choice instrument consists of 21 questions containing ten subconcepts on stoichiometry material, namely Lavoisier's Law, Avogadro's Hypothesis, Proust's Law, Dalton's Law, Gay-Lussac's Law, Relative Atomic Mass, Relative Molecular Mass, Mole Concept, Empirical Formula, Molecular Formula, Hydrate Compounds, and Substance Levels. Class X MIPA 1 and X MIPA 4 were selected to determine research samples by purposive sampling criteria.

Misconceptions That Occur in Students

Based on the study results, the percentage of student understanding categories was obtained in each subconcept of stoichiometric material. Percentage data based on the category of learners' understanding in each subconcept of the material is presented in Table 3—percentage Based on Student Understanding Categories on Each Subconcept of Stoichiometric Material.

Table 3. Percentage Based on Student Understanding Categories on Each Subconcept of Stoichiometric Material

Subconcepts	Items	Percentage			
		M	L	P	E
Lavoisier's Law	1, 3	12.68%	36.62%	47.18%	3.53%
Avogadro's Hypothesis	2	49.30%	46.48%	4.23%	0.00%
Proust's Law	4, 5	35.21%	54.23%	6.34%	4.23%
Dalton's Law	6, 7	30.29%	53.52%	12.68%	3.53%
Gay-Lussac's Law	8, 9	26.06%	57.75%	14.79%	1.41%
Relative Atomic Mass and Relative Molecular Mass	10, 11, 12	25.82%	56.81%	13.62%	3.76%
Mole Concept	13, 14, 15, 16	24.65%	61.27%	8.10%	5.99%
Empirical Formula and Molecular Formula	17, 18	21.13%	62.68%	9.86%	6.34%
Hydrate Compounds	19	19.72%	70.42%	8.45%	1.41%
Substance Levels	20, 21	17.61%	73.24%	6.34%	2.69%
Highest		49.30%	73.24%	47.18%	6.34%
Lowest		12.68%	36.62%	4.23%	0.00%

Descriptions: Misconception (M), Lack of Knowledge (L), Mistake (E), and Understand the Concept (P).

Misconceptions of students based on the highest stoichiometric subconcept are found in the subconcept of Avogadro's Hypothesis (49.30%), while the lowest is in the subconcept of Lavoisier's Law (12.68%). For the subconcept of the Avogadro Hypothesis, it means that pure learners experience misconceptions or lack of understanding of concepts and are not due to errors or errors in calculating.

Misconceptions experienced by students discussed must be independent of students' coincidental answers. Therefore, significant misconceptions must first be determined. Data on overall significant misconceptions are presented in Table 4. Significant Misconception Data.

Table 4. Significant Misconception Data

Subconcepts	Items	Answer-Reason Pattern	F	%
Lavoisier's Law	1	B-A	2	2.82%
		B-C	2	2.82%
	3	E-E	3	4.23%
Avogadro's Hypothesis	2	A-B	21	29.58%
Proust's Law	4	D-C	10	14.08%
	5	D-A	7	9.86%
Dalton's Law	6	E-D	3	4.23%
	7	C-B	18	25.35%
Gay-Lussac's Law	8	B-C	5	7.04%
	9	C-C	7	9.86%
Relative Atomic Mass and Relative Molecular Mass	10	A-C	9	12.68%
	11	D-B	6	8.45%
	12	A-B	3	4.23%
		A-C	3	4.23%
Mole Concept	13	C-C	6	8.45%
	14	C-C	7	9.86%
	15	A-A	3	4.23%
		C-C	3	4.23%
	16	B-C	2	2.82%
		C-C	2	2.82%
Empirical Formula and Molecular Formula	17	B-B	5	7.04%
	18	C-C	4	5.63%
Hydrate Compounds	19	D-C	3	4.23%
Substance Levels	20	C-C	4	5.63%
	21	C-D	4	5.63%

Table 4 shows subconcepts and question items that indicate significant misconceptions marked in blue. Subconcepts that experience significant misconceptions are found in subconcepts number 2, namely Avogadro's Hypothesis (MS-1), number 3, namely Proust's Law (MS-2), number 4, namely Dalton's Law (MS-3), and subconcept number 7, namely Relative Atomic Mass and Relative Molecular Mass (MS-4).

1. Avogadro's Hypothesis (MS-1)

The misconception in the subconcept of Avogadro's Hypothesis (29.58%) is a significant misconception with the highest percentage compared to other subconcepts. It falls into the category of original misconceptions, with an average confidence rating of 4.63. In this question point, students assume that a substance of the same volume will have the same number of particles at the same temperature and pressure. In other words, learners assume that Avogadro's Hypothesis applies to the entire phase of matter. However, the correct concept is that Avogadro's hypothesis applies only to substances with a gaseous phase. The form of misconception in question point number 2 is similar to research conducted by Riski Norjana et al. (Norjana & Joharmawan, 2016), where students assume that at the same temperature and pressure, the ratio of the number of moles of substances is the same as the volume ratio. Students must learn that the substance in the Avogadro Hypothesis is gaseous.

2. Proust's Law (MS-2)

Misconceptions that occur in the subconcept of Proust's Law (14.08%) are included in the category of original misconceptions with an average confidence rating of 4.35. The misconception in the subconcept of Proust's Law is that students consider that the ratio of the mass of elements X and Y is equal to the ratio of their coefficients. In this misconception, students solve problems about Proust's Law without involving the concept of Proust's Law, causing errors. However, the concept formed needs to be corrected, where the correct concept should state that the reaction coefficient is proportional to the number of moles and volume, not the mass of the compound. Cases like this also occur in Wahyuni's (Wahyuni, 2010) research, which states that students consider the comparison of coefficients to express mass comparison. In addition, errors in the use of basic chemical law concepts also occurred in Wiwiana's research (Wiwiana et al., 2020), where students did not use the concept of Lussac's Gay Law on questions about Lussac's Gay Law, and also in Emilia's research (Damayanti, 2017) where students incorrectly solved questions about Prous's Law using Lavoisier's Law.

3. Dalton's Law (MS-3)

Misconceptions in the subconcept of Dalton's Law (25.35%) fall into the category of original misconceptions, with an average confidence rating of 4.55. The misconception in the subconcept of Dalton's Law is that students assume that the oxygen mass ratio is determined based on the amount of oxygen mass in each compound. This is different from the correct concept, where in Dalton's Law, if two elements form two or more compounds, for the mass of one of the same elements, then the mass of the other element will be compared as an integer and a simple number. This is in line with the misconception that occurred in the research of Norjana et al. (Norjana & Joharmawan, 2016), where students assume the mass of oxygen in SO_3 and SO_2 is the same, regardless of whether the mass of sulfur in both compounds is the same or not.

4. Relative Atomic Mass and Relative Molecular Mass (MS-4)

Misconceptions in the subconcepts of Relative Atomic Mass and Relative Molecular Mass (12.68%) are included in the original misconception category with an average confidence rating of 4.57. The misconception is that students assume that relative atomic mass expresses the ratio of the average mass of one molecule of an element to 1/12 the mass of one C-12 atom. The correct concept is relative atomic mass, which expresses the ratio of the average mass of one atom of an element to 1/12 of the mass of one C-12 atom (Chang, 2005). Students cannot distinguish the concept of relative atomic mass or Ar with the relative molecular mass or Mr. This misconception is also found in the research of Nursiwin (2014) and Emilia (2017), where students consider relative atomic mass or Ar equal to relative molecular mass or Mr (Damayanti, 2017; Nursiwin, 2014).

Percentage of Students Who Experience Misconceptions

Based on the results of the study, the percentage of student understanding categories was obtained in all subconcepts of stoichiometric material, namely the categories of misconceptions (M), lack of understanding of concepts (L), understanding concepts (P), and errors (E). This data shows the frequency and percentage of students who experience misconceptions about stoichiometric material. Percentage data based on student comprehension categories in the whole material are presented in Table 5. Percentage data by student comprehension category.

Table 5. Percentage data by student comprehension category

Description	M	L	P
Frequency	18	41	9
Percentage	25,35%	57,75%	12,68%

Causes of Misconceptions

The causes of misconceptions are categorized based on the source of misconceptions, namely from students, notebooks, package books, and teachers (Suparno, 2013).

a. Teacher

Misconceptions experienced by students can be caused by teachers who teach the field of study. Misconceptions from teachers are related to technical learning, learning methods, and teacher delivery. Technical learning is carried out hybridly (two meetings are held online, and one is held offline). Technical learning like this is one of the causes of misconceptions experienced by students because it will affect the overall understanding of concepts. When viewed from the research data, some basic laws of chemistry taught online become one of the subconcepts with significant misconceptions. Teachers in the field of chemistry study use the lecture method in delivering stoichiometry material, where the technical delivery is by providing material for each basic legal sub-concept then providing examples, and then practicing questions. Therefore, a review must be carried out to improve the quality of the teaching and learning process (Rohmah, et al., 2019)

Teachers use the lecture learning method to deliver stoichiometric material, where the technical delivery is by providing material for each subconcept of fundamental law, giving examples, and practicing questions. The result of this learning method is that students are considered passive at the time of learning, which will affect students' ability to understand the concept as a whole (Wiwiana et al., 2020). Apart from that, the teacher's delivery of stoichiometry learning using concept delivery and examples makes the teacher less focused on explaining the hierarchical relationships of existing concepts. This causes students to have difficulty understanding the relationships between concepts (Norjana & Joharmawan, 2016). Micro teaching can provide feedback in the form of developing discovered strengths or improving student/potential teacher deficiencies in teaching activities (Olensia, 2018).

b. Student

Misconceptions originating from students are caused by several things, namely the wrong conception of learners, dependent algorithmic phenomena, students' abilities, and students' interest in chemistry learning.The wrong conception of students is caused by incomplete reasoning of students (Suparno, 2013), even though the teacher's explanation is complete and correct. This is evidenced through interviews and analysis of 4TMC, especially on the subconcepts of Avogadro's Hypothesis and Dalton's Law. Where learners understand that Avogadro's Hypothesis applies to all substances. In addition, on the subconcept of Dalton's Law, learners do not notice that there must be a mass of one of the same elements. The wrong conception of students can also be caused by inappropriate interpretations of concepts based on students' thoughts (Suparno, 2013). This can be seen from the students' understanding, which is different from what the teacher explains, where students consider the comparison of coefficients equal to the comparison of mass.

Students ' misconceptions are also supported by algorithmic-dependent phenomena that will result in a superficial understanding of concepts (Anugrah, 2019). This phenomenon shows that students' success in solving stoichiometric problems does not mean that students also need to understand the concept (Anugrah, 2019). In the subconcept of Proust's Law, students can solve problems with correct calculations based on reading the narrative of the problem and then looking at the problem graph. However, when asked about the concept, students need help to need help to answer correctly. In addition, learners know the formula for calculating Ar and Mr but need to be corrected to understand the concepts of Ar and Mr.

Students' ability is also the cause of student misconceptions in stoichiometric material. The ability of students is related to how students analyze problems. From the results of interviews and 4TMC analysis, students needed to be corrected in analyzing questions related to Proust's

Law, which resulted in the resolution of this problem not involving the concept of Proust's Law. Most misconceptions come from students' lack of understanding of chemical concepts that support chemical calculations, such as matter and its changes (atoms, molecules, and ions) as well as the basic laws of chemistry (Anugrah, 2019).

It is undeniable that misconceptions originating from students are also related to students' interest in learning chemistry, especially stoichiometric material. Students are considered to have less interest when learning chemistry, which can interfere with students' overall transfer of concepts. The low interest of students is also related to the learning method presented by the teacher. This is similar to research conducted by Wiwiana (2020), where students' low interest in studying chemistry was one of the causes of misconceptions. The low interest of students is also related to the learning methods presented by the teachers. A shift in students' misconceptions is a shift in the status of misconceptions that occurs in students after reducing activities using the ECIRR learning model Wulandari, & Rusmini (2020). The main obstacle to the problem-solving stage is that students are not used to solving problems using the problem-solving stage, especially in terms of making plans and checking again (Maemanah, et al., (2019).

c. Book

Misconceptions experienced by students, apart from coming from students' thoughts, can also be caused by the books used (Suparno, 2013). In this study, misconceptions were found in student notebooks. Examination of notebooks obtained evidence that students only wrote down the essence of the material and then wrote down the algorithmic formula. This is found in several student notes regarding Avogadro's Hypothesis, Dalton's Law, and Ar / Mr.

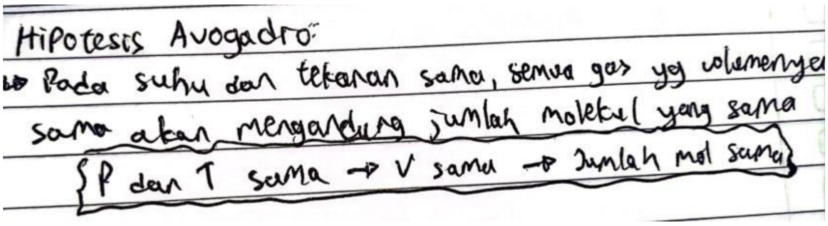

Figure 1. Sample of Student's Notebook

Figure 1. shows that students assume that at the same temperature and pressure, substances with the same volume will have the same number of particles. Avogadro's Law should read: "All gases that have the same volume under the same pressure and temperature have the same number of particles or molecules. Student notebooks are one of the causes of student misconceptions as in research conducted by Nursiwin (Nursiwin, 2014), wherein student notebooks misconceptions were found about molecular formulas and empirical formulas. Notebooks should be a means of supporting students in order to understand the material. This is based on research conducted by Climenhaga (Dewi et al., 2014), who found that notes are essential to increase understanding of what teachers have taught.

CONCLUSION AND RECOMMENDATIONS

Several conclusions were obtained from the data from the research and discussion of this study. Significant misconceptions in grade X students at SMA Negeri 1 Jetis on stoichiometry material occur in the subconcepts of Avogadro's Hypothesis, Proust's Law (Law of Fixed Comparison), Dalton's Law (Law of Multiple Comparisons), and Determination of Relative Atomic Mass (Ar) and Relative Molecular Mass (Mr). The percentage of grade X students at SMA Negeri 1 Jetis on stoichiometric material who experience misconceptions is 25.35%, classified as low.The cause of the misconception experienced by class X students at SMA Negeri 1 Jetis on this stoichiometric material comes from teachers, students, and books.

Misconceptions originating from teachers are related to learning methods, techniques, and delivery. Misconceptions originating from students are caused by wrong conceptions of students, dependent algorithmic phenomena, student abilities, and lack of student interest. At the same time, the misconception from the book is the existence of concepts that need to be more appropriate in the student's notebook.

REFERENCES

Agustin, U., Susilaningsih, E., Nurhayati, S., & Wijayati, N. (2022). Pengembangan instrumen tes diagnostik four-tier multiple choice untuk identifikasi miskonsepsi siswa pada materi kesetimbangan kimia. *Chemistry in Education*, *11*(1), 1–7. http://journal.unnes.ac.id/sju/index.php/chemined

Aini, R. G., Ibnu, S., & Budiasih, E. (2016). Identifikasi miskonsepsi dalam materi stoikiometri pada siswa kelas x di sman 1 malang melalui soal diagnostik three-tier. *Jurnal Pembelajaran Kimia (J-PEK)*, *01*(2), 50–56.

Anugrah, I. R. (2019). Telaah topik stoikiometri sma: miskonsepsi dan strategi pembelajarannya. *Orbital: Jurnal Pendidikan Kimia*, *3*(2).

Bunyamin. (2021). *Belajar dan pembelajaran: Konsep Dasar, Inovasi, dan Teori* (Hasmawati, Ernawati, Susarah Lobo, Lismawati, Hamka, & A. S. Wati, Eds.). UPT UHAMKA Press. www.uhamkapress.com

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* (L. Simarmata, Ed.; 3rd ed.). Penerbit Erlangga.

Damayanti, E. T. (2017). analisis miskonsepsi peserta didik dengan menggunakan metode certainty of response index (cri) termodifikasi pada konsep stoikiometri di sma negeri 5 semarang *SKRIPSI Diajukan untuk Memenuhi Sebagian Syarat Guna Memperoleh Gelar Sarjana S1 dalam Ilmu Pendidikan Kimia*.

Depdiknas. 2006. Panduan Penyusunan Kurikulum Tingkat Satuan Pendidikan Dasar dan Menengah. Jakarta : Badan Standar Nasional Pendidikan.

Dewi, A.G & Indrawati, K.R (2014). Perilaku Mencatat dan Kemampuan Memori pada Proses Belajar. *Jurnal Psikologi Udayana*, *1*(2), 241–250.

Ernawati, D., Ashadi, & Utami, B. (2015). Upaya peningkatan prestasi belajar dan kemampuan berpikir kritis siswa kelas x mia 7 dengan menggunakan metode pembelajaran problem solving pada materi stoikiometri di sma negeri 1 sukoharjo tahun pelajaran 2014/2015. *Jurnal Pendidikan Kimia (JPK)*, *4*(4), 17–26. http://jurnal.fkip.uns.ac.id/index.php/kimia

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a

Islami, D., Munawaroh, F., Hadi, W. P., & Wulandari, A. Y. R. (2018). analisis miskonsepsi siswa pada mata pelajaran ipa materi listrik statis menggunakan four tier test. *Science Education National Conference*, 71–77.

Ismail, I. I., Samsudin, A., Suhendi, E., & Kaniawati, I. (2015). Diagnostik Miskonsepsi Melalui Listrik Dinamis Four Tier Test. *Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains*, 381–384.

Karim, A. (2020). Identifikasi miskonsepsi siswa pada konsep stoikiometri menggunakan four-tier multiple choice test di sma negeri 8 kota tangerang selatan [Program Studi Pendidikan Kimia]. UIN Syarif Hidayatullah.

Maemanah, S., Suryaningsih, S., & Yunita, L. (2019). Kemampuan pemecahan masalah melalui model flipped classroom pada pembelajaran kimia abad ke 21. Orbital: Jurnal Pendidikan Kimia, 3(2), 143-154.

Norjana, R., & Joharmawan, R. (2016). Identifikasi tingkat pemahaman konsep hukum-hukum dasar kimia dan penerapannya dalam stoikiometri pada siswa kelas x ipa di man 3 malang. *01*(2).

Nursiwin. (2014). *Menggali miskonsepsi siswa sma pada materi perhitungan kimia menggunakan certainty of response index*.

Olensia, Y. (2018). Analisis pelaksanaan micro teaching calon guru kimia di FITK UIN Raden Fatah Palembang. Orbital: Jurnal Pendidikan Kimia, 2(2), 58-70.

Rohmah, M., Ibnu, S., & Budiasih, E. (2019). Pengaruh real laboratory dan virtual laboratory terhadap kualitas proses pada materi kesetimbangan kimia. Orbital: Jurnal Pendidikan Kimia, 3(1), 1-14.

Rusilowati, A. (2015). Pengembangan Tes Diagnostik sebagai Alat Evaluasi Kesulitan Belajar Fisika. *Prosiding Seminar Nasional Fisika Dan Pendidikan Fisika (SNFPF) Ke-6*, 1–10.

Sariati, Kadek, N., Suardana, Nyoman, I., Wiratini, & Made, N. (2020). analisis kesulitan belajar kimia siswa kelas xi pada materi larutan penyangga. *Jurnal Ilmiah Pendidikan Dan Pembelajaran*, *4*(1), 86–97.

Suparno, P. (2013). *Miskonsepsi dan Perubahan Konsep dalam Pendidikan Fisika* (2nd ed.). Grasindo.

Wahyuni, E. (2010). *Identifikasi konsep sukar dan salam konsep dalam pokok bahasan perhitungan kimia pada siswa SMA Negeri 8 Malang*. Universitas Negeri Malang.

Winarni, S. (2016). Miskonsepsi Kimia yang Disebabkan Pernyataan Nonproposisi. *Jurnal Pendidikan Sains*, *4*(4), 122–129.

Wiwiana, W., Hasri, H., & Husain, H. (2020). Analisis Miskonsepsi Peserta Didik Menggunakan Certainty of Response Index (CRI) pada Materi Stoikiometri. *Chemistry Education Review*, *4*(1), 2597. https://doi.org/10.26858/cer.v4i1.13315

Wulandari, C. A., & Rusmini, R. (2020). Pembelajaran ecirr dalam mereduksi miskonsepsi pada materi stoikiometri kelas x sma. Orbital: Jurnal Pendidikan Kimia, 4(1), 1-15.

Yusuf, A. M. (2016). *Metode Penelitian Kuantitatif, Penelitian Kualitatif dan Penelitian Gabungan*. Kencana.

Zafitri, R. E., Fitriyanto, S., & Yahya, F. (2018). Pengembangan Tes Diagnostik untuk Miskonsepsi pada Materi Usaha dan Energi Berbasis Adobe Flash Kelas XI di MA NW Samawa Sumbawa Besar Tahun Ajaran 2017/2018. *Jurnal Kependidikan*, *2*(2), 19–34.

Zidny, R., Sopandi, W., & Kusrijadi, A. (2013). Analisis pemahaman konsep siswa sma kelas x pada materi persamaan kimia dan stoikiometri melalui penggunaan diagram submikroskopik serta hubungannya dengan kemampuan pemecahan masalah. *Jurnal Riset Dan Praktik Pendidikan Kimia*, *1*(1), 27–36.