



## Analysis of Students' Level of Understanding of Hydrocarbon Concepts Using a Three-Level Diagnostic Multiple-Choice Approach

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### Abstract

This research aims to determine students' conceptual understanding ability of hydrocarbon material using a three-tier multiple-choice diagnostic test instrument. The research was conducted at SMA Negeri 2 Wonosari using a descriptive qualitative approach. The research was carried out in the even semester of the 2024/2025 academic year. The research subjects were the students of class XI B at SMA Negeri 2 Wonosari, with a sample size of 28 students. The instrument used consisted of 15 three-tier multiple-choice questions covering answers, reasoning, and the student's confidence levels. The validity and reliability of the instrument were tested through expert analysis and empirical testing using the Rasch model. Data collection was carried out using the three-tier multiple-choice test. After obtaining the students' responses, the answers were analyzed and categorized based on conceptual understanding levels: Understanding the Concept (UC), Negative Misconception (NM), Positive Misconception (PM), and Not Understanding the Concept (NUC). The results indicate that the average percentage of conceptual understanding was 29.05%, categorized as low; negative misconceptions were 23.10%, also categorized as low; positive misconceptions were 10.24% categorized as very low; and not understanding the conceptions 37.62%, categorized as low. In conclusion, students of class XI B at SMA Negeri 2 Wonosari showed the lowest average level of conceptual understanding compared to those experiencing misconceptions or lacking scientific understanding of the concept.

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## 1. INTRODUCTION

Education plays a crucial role in ensuring the sustainability of a nation's existence and serves as a key contributor across various aspects of life, as the quality of a nation's life is strongly linked to the educational level of its people. Given the importance of education for a nation, the government, especially through the national education department, continues to make various changes and reforms to the education system to improve the quality of national education (Lukum et al., 2023).

Chemistry is a discipline that many high school students tend to be less interested in (Subagia, 2014). This occurs because, although chemistry offers

numerous benefits to humans and is closely connected to daily life, many students continue to struggle with grasping its concepts (Muderawan et al., 2019). The study of chemistry is interconnected, as its concepts are linked and develop sequentially (Jusriana et al., 2022). One of the primary subjects introduced in the high school chemistry curriculum is hydrocarbons (Romadhona et al., 2020).

Hydrocarbons are a significant component of chemistry that demands a thorough comprehension of concepts. Consequently, students must not only listen attentively to the teacher's explanation but also actively

engage in the learning process to fully grasp the material (Nur Annisa, 2013).

Among the various materials taught in chemistry, hydrocarbons are sometimes seen by students as difficult to understand and therefore not very favored by students. According to Pratiwi et al., (2013) hydrocarbons are difficult for students to understand because of several negative things, namely: (1) A large amount of detailed knowledge and material specific terms of hydrocarbons that students are expected to remember, (2) Many of the terms, often appearing as chemical compound names, are rarely observed in everyday contexts, making them seem unfamiliar and challenging for a large number of students. (3) the broad scope of hydrocarbon material, which requires more time to be delivered in class.

Some students find it difficult to understand hydrocarbon material because, in addition to memorizing the types of compounds, they must also be able to recognize the basic structure/functional groups and write or describe the structural formula of the compound. Chemistry requires understanding or mastery of concepts, each of which is related to the next. During the learning process, students often face misunderstandings or misconceptions about concepts. This is caused by initial misconceptions (knowledge or beliefs that students already have before participating in classroom learning), such as previously learned material regarding the properties of hydrocarbons, including the Lewis structure and periodic table of elements (Reny et al., 2023).

Concept understanding is the ability to capture the meaning understanding such as being able to express or describe a material presented into a form that is better understood or able to be able to explain using language, which is able to provide interpretation apply it (Musa et al., 2023).

According to Widiyatmoko & Shimizu, (2018), An important method for evaluating the enhancement of students' conceptual skills involves the implementation of diagnostic testing to gain insights into their level of understanding. The diagnostic assessment employed is a three-tier multiple choice instrument that consists of three components within each item: the first tier presents a multiple-choice question, the second tier requires students to provide a justification for their chosen answer, and the third tier evaluates the students' confidence level in the response they selected (Saat et al., 2016).

Diagnostic tests are a type of learning evaluation that can be carried out by teachers to identify student weaknesses, so that they can provide appropriate interventions to overcome these deficiencies (Arikunto, 2018). In line with this, the application of the three-tier multiple choice diagnostic test at the beginning of learning is very important to obtain a more complete picture of students' understanding and confidence in the material.

Implementing the three-tier multiple choice diagnostic test at the beginning of the learning process is highly valuable, as it enables teachers to gain insights not only into students' confidence in their answers but also into the reasoning that supports their selected choices. In this way, teachers can identify students' understanding in greater depth (Nazura et al., 2021). The three-tier multiple choice diagnostic test offers various advantages, such as its ability to deeply detect learners' conceptual misunderstandings, pinpoint topics that need additional instructional focus, and assist teachers in designing more efficient learning interventions aimed at reducing misconceptions (Elvia et al., 2020).

## **2. METHOD**

### **a. Type of research**

This study adopts a qualitative approach by employing descriptive methods to analyze the data. According to Chariri (2009), qualitative research is based on an exploratory concept, which involves an in-depth study of one or several contextual cases. This research was conducted in a real (natural) situation with the aim of exploring and understanding a phenomenon, including what happened, the reasons for its occurrence, and the process of the event.

The research employs a descriptive method to systematically present and analyze the collected data. According to Sugiyono (2010) Explaining that the descriptive method is an approach used to analyze data by presenting or describing the information that has been collected as it is, without making modifications or interpretations. This study explores students' ability to understand the concept of hydrocarbon compounds through the use of a three-level multiple-choice diagnostic instrument.

### **b. Time and Place**

This research was conducted at SMA Negeri 2 Wonosari in 2025. The school is located at Jalan Transmigrasi, Sukamulya Village, Boalemo Regency,

Gorontalo Province. The research time used in this study was approximately 4 months in the even semester of the 2024/2025 academic year, adjusted to the stages of research activities.

**c. Target**

The targets in this study were students of class XI B at SMA Negeri 2 Wonosari as many as 28 students.

**d. Data Collection Techniques and Procedures**

Data collection techniques and procedures are obtained through the observation process, giving tests to students, interviews, and documentation.

**e. Instrument**

The study utilized a Three-Level Multiple Choice Diagnostic Instrument specifically developed for the topic of hydrocarbons, where each item covers three different levels aiming to evaluate knowledge, reasoning, and confidence. The first level consists of student answers, the second level is the choice of student reasons, and the third level assesses the student's level of confidence in their chosen answer. The Three Level Multiple Choice instrument used in this study consisted of a total of 15 test items. The questions used in this study cover three cognitive domains related to Higher Order Thinking Skills (HOTS), specifically C4 (analyze), C5 (evaluate), and C6 (create), as outlined in Bloom's Taxonomy.

**f. Data Analysis Technique**

The data analysis technique used in this study employed percentage-based analysis, which was conducted in two main stages: the first stage focused on analyzing students' responses, while the second stage involved categorizing the results into three groups- conceptual understanding, misconceptions, and lack of conceptual understanding. A detailed explanation of the data analysis is as follows:

1. Students' Concept Understanding Ability on Hydrocarbon Materials at SMA Negeri 2 Wonosari Through Three-Tier Multiple Choice Diagnostic Tests.

The data used in this study were obtained from the results of a Three-Level Multiple Choice test focusing on hydrocarbon materials. Furthermore, test results were examined by calculating the scores and percentages of students who answered correctly and those who answered incorrectly for each test item. Data was analyzed by calculating the score and percentage of students who answered each question correctly and

incorrectly. The categories of students' concept understanding are shown in the following table:

Table 1. Category of students' concept understanding based on students' answers using the three-tier multiple choice diagnostic instrument

Problem Level Analysis	Answer Type			Category
	First Level	Second Level	Third Level	
Three-Tier Multiple Choice Test	Correct Answer	Correct Reason	Sure	Understanding the Concept
	Correct Answer	Correct Reason	Not Sure	Not Understanding the Concept
	Wrong Answer	Correct Reason	Not Sure	Not Understanding the Concept
	Correct Answer	Wrong reason	Not Sure	Not Understanding the Concept
	Wrong Answer	Wrong reason	Not Sure	Not Understanding the Concept
	Wrong Answer	Correct Reason	Sure	Misconception (False Negative)
	Wrong Answer	Wrong reason	Sure	Misconception (False Negative)
	Correct Answer	Wrong reason	Sure	Misconception (False Positive)

(Rahmatih et al., 2023)

2. Percentage of Students in the Conceptual Understanding, Misconception, and Non-Conceptual Understanding Categories on Hydrocarbon Materials

To determine the percentage of students categorized as having conceptual understanding, not understanding, or misconceptions, the following formula was used:

$$P_{(1,2,3)} = \frac{S(1.2.3)x^2}{2!J_S} x = 100\% \quad (1)$$

Description:

- P<sub>1</sub> = Percentage of students who understand the concept
- S<sub>1</sub> = Number of students who understand the concept
- P<sub>2</sub> = Percentage of students with misconceptions
- S<sub>2</sub> = Number of students with misconceptions
- P<sub>3</sub> = Percentage of students who do not understand the concept
- S<sub>3</sub> = The number of students who do not understand the concept
- J<sub>S</sub> = Total number of students taking the test

The criteria used to interpret data related to student' understanding of concepts and students' ability to understand certain concepts are presented in the following table:

Table 2. Criteria for describing the results of student understanding data

Interval	Criteria
81%-100%	Very High
61%-80%	High
41%-60%	High enough
21%-60%	Low
0%-20%	Very Low

(Djarwo, 2018)

### 3. RESULT AND DISCUSSION

#### 3.1. Result

The analysis was conducted based on students' answers to the Three-Tier Multiple Choice instrument. The instrument consists of a three-level objective multiple-choice test, where the first level captures the student's answer, the second level includes the justification given by the student, and the third level shows how confident the student is in their answer. The instrument is able to categorize students' conceptual understanding into four different classifications: those who understand the concept (PK), those who have negative misconceptions (MN), those who have positive misconceptions (MP), and those who do not understand the concept at all (TPK).

##### 1. Validity and Reliability Test Results

The results of the instrument validity assesment conducted by two lecturers and one chemistry teacher showed that the instrument reached the validity level with an average value of 93.33% and was classified as valid. In addition to the validity test conducted by the 3 validators. In this study, the validity test was also carried out on students at Madrasah Aliyah Salafiyah Syafiiyah by using Rasch modeling, specifically in the Item Statistics section, the Misfit Order (Item Fit Order) refers to the level of item fit (validity), which indicates whether each item performs nomarily or abnormally in fulfilling its measurement function (Parwati, 2024).

According to Fadhilah & Yuniarti (2024), In the Rasch model framework, the criteria for determining whether an item is acceptable are based on certain statistical indicators, namely outfit mean square, outfit z-standard, and point measure correlation. The acceptable range for infit mean square (MNSQ):  $0.5 < \text{MNSQ} < 1.5$ ; for z-standard (ZSTD):  $-2.0 < \text{ZSTD} < +2.0$ ; and for point

measure correlation (Pt Measure Corr):  $0.4 < \text{Pt Measure Corr} < 0.85$ .

Based on Table 3, the Item Statistic: Misfit Order analysis was conducted using Winsteps version 3.73 for Windows to assess the validity of items included in the Three-Tier Multiple Choice Diagnostic Instrument. If all three criteria for an item are met, then the item is considered 'feasible' and considered to be of good quality. However, if only two or one criterion is met, then the problematic item can still be maintained without needing to be replaced, thus, the item is categorized as "appropriate" and still suitable for use (Muntazhimah et al., 2020).

Table 3. Test item statistics: misfit order

No	OUTFIT		PT- MEASURE CORR	Compliant Status	Interpretation
	MNSQ	ZSTD			
1	0.81	-0.7	0.51	3 Criteria	In accordance
2	1.26	0.8	<b>0.10</b>	2 Criteria	In accordance
3	0.68	-1.5	0.60	3 Criteria	In accordance
4	0.93	-0.1	0.21	3 Criteria	In accordance
5	0.68	-1.5	0.60	3 Criteria	In accordance
6	1.17	0.6	0.37	3 Criteria	In accordance
7	0.83	-0.6	0.59	3 Criteria	In accordance
8	1.31	0.7	0.22	3 Criteria	In accordance
9	1.01	0.1	0.52	3 Criteria	In accordance
10	1.05	0.3	0.31	3 Criteria	In accordance
11	1.26	0.8	0.32	3 Criteria	In accordance
12	0.83	-0.6	0.54	3 Criteria	In accordance
13	0.67	-1.0	0.50	3 Criteria	In accordance
14	0.90	-0.2	0.56	3 Criteria	In accordance
15	0.79	-0.7	0.50	3 Criteria	In accordance

Table 4. Summary of Fit Statistics

	Responden (N=27)	Item (N=15)
Mean	-0.11	0.00
Standard Defiasi	0.42	0.40
Realibility	0.68	0.81
Separation index (Realibility)	1.44	2.09
Cronbach Alpha (KR-20) = 0.65		
Chi-Square: 822.60 with 362		
Dfp = 0.0000		

In Table 4, it can be seen that all items of the Outfit Mean Square value have met the criteria for the suitability of the items. The results of the Rasch model analysis on the reliability test (Summary Statistics) show

that the person reliability value is 0.68, while the item reliability value reaches 0.81. This shows that the three-tier multiple choice diagnostic instrument has sufficient person reliability and has good item reliability. As for the Alpha Cronbach value, it reflects the overall interaction between the respondent and the test item in a comprehensive manner. Based on Table 4, the Cronbach's Alpha value is 0.65, which means that the reliability of the interaction between people and items is at a moderate level.

## 2. Percentage of Students Based on Answers Using The Three-Tier Multiple Choice Diagnostic Instrument

The average number of students who gave the correct answer (indicating Conceptual Understanding) for each question is detailed as follows: Problem number 1 was 46.43%, problem number 2 was 21.43%, problem number 3 was 28.57%, problem number 4 was 53.57%, problem number 5 was 25.00%, problem number 6 was 60.71%, problem number 7 was 7.14%, problem number 8 was 7.14%, question number 9 by 39.29%, question number 10 by 32.14%, question number 11 by 39.29%, question number 12 by 3.57%, question number 13 by 28.57%, question number 14 by 7.14%, and question number 15 by 35.7%. In general, the average percentage of students who answered correctly (showing conceptual understanding) on hydrocarbon material was 29.05%.

Based on the overall average percentage of students categorized as understanding the concept, showing negative misconceptions, showing positive misconceptions, and having no conceptual understanding, the comparison of these proportions is illustrated in the following graph:

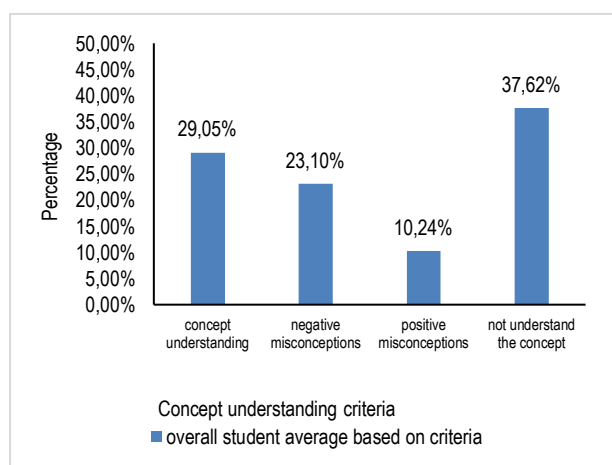


Figure 1. Criteria for student concept understanding

## 3.2. Discussion

Research findings from a study involving 28 students of class XI B at SMA Negeri 2 Wonosari on hydrocarbon material, assessed using a three-tier multiple choice diagnostic instrument, showed varying percentages among students who understood the concept, had positive or negative misconceptions, and who had no conceptual understanding. These results indicate that the majority of students have not successfully integrated factual knowledge, conceptual understanding, and logical reasoning in answering the questions.

From the analysis of students' answers obtained from the three-tier multiple choice diagnostic instrument, their level of conceptual understanding will be discussed in the following sections:

- 1) Students' concept understanding ability in Analyzing carbon compounds through carbon compound identification.

Problem Question number 1 tested the understanding of identifying carbon compounds through combustion reactions. Some students were able to understand that limestone water becomes cloudy because  $\text{CaCO}_3$  is formed from  $\text{CO}_2$  gas. However, many students had misconceptions, such as stating that CO gas or charcoal is produced from complete combustion, and assuming that CO causes limestone water to change color. This shows basic misconceptions about the combustion of carbon compounds.

- 2) Students' concept understanding ability in Analyzing the differences between organic and inorganic carbon compounds.

Problem Question number 2 deals with the difference between organic and inorganic compounds. Many students mistakenly assume that all organic compounds contain nitrogen and that inorganic compounds never contain carbon. Students tend to memorize without understanding that organic compounds have C-H bonds and flammability, while inorganic compounds may contain C but are not part of the organic structure.

- 3) Students' concept understanding ability in Analyzing the characteristics of carbon atoms on the properties and ways of bonding carbon atoms.

Question number 3 assesses understanding of the characteristics of carbon atoms. Students who understood were able to mention the ability to catenate

and form 4 covalent bonds. However, misconceptions arose such as assuming carbon has 6 valence electrons or cannot double bond, indicating a misunderstanding of electron configuration and bond types.

- 4) Students' concept understanding ability in Organizing hydrocarbon compounds based on their structure and their relationship with the properties of compounds.

Question Problem number 4 assesses the ability to organize hydrocarbon compounds based on their structure and properties. Most students were able to answer correctly, but others failed to understand the effect of branching and chain length on boiling point. Some even misidentified the structure of the compound and its name.

- 5) Students' concept understanding ability in Analyzing the properties of Alkanes.

Problem number 5 focuses on the nature of alkanes. There are still many students who think alkanes have double bonds or that all alkanes are solid. This misconception is due to a misunderstanding of the single bond structure in alkanes and the effect of the number of carbon atoms on physical form.

- 6) Students' concept understanding ability in Evaluating types of hydrocarbon compounds based on structure and chemical reactions.

Problem number 6 evaluates the type of hydrocarbon based on addition reactions. Many students can recognize that  $C_6H_{14}$  is an alkane that does not react with  $Br_2$ . However, students with misconceptions stated that  $C_6H_{14}$  is an alkene or alkyne, and did not understand that single bonds do not undergo addition reactions.

- 7) Students' concept understanding ability in Assessing the negative impact on the environment from the use of hydrocarbons.

Question 7 tested understanding of the impact of burning hydrocarbons. The majority of students answered that combustion increases carbon levels in the atmosphere, but gave erroneous reasons, such as lowering global temperatures. This misconception shows a lack of integration between chemistry concepts and environmental issues.

- 8) Students' concept understanding ability in Analyzing the physical properties of hydrocarbons.

Problem number 8 assesses understanding of the boiling point of hydrocarbons. Many students did not understand that saturated compounds (alkanes) such as

$C_6H_{14}$  have a higher boiling point than alkenes ( $C_6H_{12}$ ) due to stronger intermolecular interactions. Most students answered the opposite with the wrong molecular mass reason.

- 9) Students' concept understanding ability in Analyzing the structure and properties of hydrocarbon compounds based on understanding the peculiarities of carbon atoms and the classification of compounds.

Problem number 9 on the classification of unsaturated hydrocarbon compounds shows that students still mix up alkanes and alkenes/alkynes. Many students stated that  $C_2H_6$  (ethane) is unsaturated, showing misconceptions in linking molecular formulas with bond types.

- 10) Students' concept understanding ability in Creating solutions to environmental problems related to hydrocarbons.

Problem number 10 assesses students' ability to create environmental solutions. The correct answer, encouraging the use of electric vehicles, was still chosen by a small number of students. Most others chose to reduce renewable energy or increase the use of fuel, which shows misconceptions in understanding environmentally friendly solutions.

- 11) Students' concept understanding ability in Analyzing tertiary C atoms in the structure of hydrocarbon compounds.

Problem number 11 deals with the analysis of tertiary carbon atoms. Many students were unable to identify the tertiary C atom correctly, some even stating that the carbon atom binds 5 other carbon atoms, which contradicts the valency of carbon. This shows a lack of understanding of carbon structure and bonding.

- 12) Students' concept understanding ability in Analyzing groups of hydrocarbon compounds based on the structure and types of reactions that occur.

Problem number 12 assessed students' understanding of addition and oxidation reactions. Most students incorrectly stated that addition reactions occur without double bond breaking or that oxidation occurs with bromine. They also incorrectly identified elimination and substitution reactions as oxidation/addition.

- 13) Students' concept understanding ability in Analyzing the boiling point relationship of hydrocarbon compounds with their relative molecular mass and structure.

Question 13 on the relationship between boiling point and structure and relative molecular mass showed that many students did not understand that compounds with longer carbon chains (e.g. heptane) have a higher boiling point because the dispersion force is greater. Instead, they answered compounds with fewer C's such as propane.

14) Students' concept understanding ability in assessing hydrocarbon combustion reactions.

Problem number 14 assesses understanding of hydrocarbon combustion. Misconceptions arose in students who did not distinguish between complete and incomplete combustion. Many students chose the wrong reaction equation but were confident in their answer, indicating negative misconceptions.

15) Students' concept understanding ability in Analyzing the names of hydrocarbon compounds according to IUPAC.

Problem number 15 relates to the IUPAC naming of unsaturated compounds. Some students were able to answer 1,3-octadiene as the correct answer. However, many also answered 1,3-heptadiene and gave incorrect reasons, such as incorrectly mentioning the number of C atoms and the position of the double bond, which showed errors in applying IUPAC rules.

16) Factors underlying students' low conceptual understanding of hydrocarbon materials were identified through interviews conducted with students.

Based on interviews with several students of Class XI B SMA Negeri 2 Wonosari, there are several main factors that cause the low concept understanding ability of students in hydrocarbon material, namely where students have difficulty in understanding the terms and structure of hydrocarbon compounds, students say hydrocarbon material is considered too heavy because there are many things that must be memorized. besides that, students lack motivation and interest in chemistry lessons because the speed of teacher explanations is not balanced with the speed of students in recording and understanding hydrocarbon material.

#### 4. CONCLUSION

Based on the findings of a study involving 28 students of class XI B at SMA Negeri 2 Wonosari using a Three-Tier Multiple Choice Diagnostic Instrument, it was revealed that students' conceptual understanding of

hydrocarbon material was still low, with only 29.05% of them showing a clear and accurate understanding of the concept. In contrast, 23.81% of students had negative misconceptions, 11.67% had positive misconceptions, and 35.47% did not understand the concept. The most difficult sub-materials to understand include the physical properties of hydrocarbons, identification of structures and reactions, and combustion of hydrocarbons. The three-tier instrument proved to be effective in revealing students' understanding and conceptual errors. The interview results also indicated that difficulties in understanding chemical terms, structural forms of compounds, the dominance of memorization, lack of interest in chemistry, and the speed of the teacher in delivering the material are factors that influence students' low mastery of concepts in hydrocarbon materials.

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