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Analysis of Multiple Representation Ability of Chemistry Education Students on Hydrocarbon

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Abstrak

This study aims to analyze students' multiple representation ability on hydrocarbon which includes macroscopic, submicroscopic, and symbolic representations. The research subjects were Chemistry Education Study Program students of FKIP Tanjungpura University class of 2022 and 2023 who had taken the Organic Chemistry of Monofunctional Compounds course, totaling 108 people. The research used a quantitative descriptive method with an instrument in the form of a description test of 9 questions, each of which represented three levels of representation. The results showed that students' macroscopic representation ability was classified as good with an average of 68.30% (batch 2023) and 64.86% (batch 2022). The submicroscopic representation ability is classified as good, with an average of 70.26% (batch 2023) and 69.59% (batch 2022). Meanwhile, the symbolic ability of the 2023 batch students was classified as sufficient with an average of 53.43%, and the 2022 batch was classified as good with an average of 67.10%. These findings indicate that students still experience difficulties, particularly in mastering symbolic representation, which is a crucial aspect in understanding hydrocarbon chemistry concepts. Therefore, training in symbolic representation mastery is necessary. The novelty of this research lies in the focus of the analysis of students' abilities in integrating the three levels of representation comprehensively on the topic of hydrocarbons, which until now has rarely been studied specifically in the context of chemistry education.

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INTRODUCTION

Learning chemistry requires high abstract thinking skills because many of its concepts cannot be observed directly. Therefore, an important approach to understanding chemistry concepts is through three levels of representation: macroscopic, submicroscopic, and symbolic (Gilbert & Treagust, 2009). Macroscopic representation refers to phenomena that can be observed directly, such as changes in color, odor, or state of matter, submicroscopic representation describes the structure of particles, atoms, and molecules that cannot be observed directly but can be visualized through models, while symbolic representation involves the use of chemical formulas, reaction equations, and other symbols to describe chemical phenomena quantitatively. These three levels are interconnected, important to master in a balanced manner, and necessary to explain chemical phenomena, considering that not all can be observed directly by human senses (Setiawan et al., 2020).

The learning process using multiple representations is expected to bridge students' understanding of complex chemical concepts (Pahriah & Hendrawani, 2020; Derman & Ebenezer, 2020). Research by Gkitzia, Salta, and Tzougraki (2020) shows that many students still struggle to transform one type of representation into another, such as from symbolic to submicroscopic. Furthermore, Widarti, Marfu'ah, and Parlan (2019) found that the systematic use of multiple representations can improve understanding of chemical concepts, particularly intermolecular forces.

The material raised in this study is hydrocarbons, which is organic chemistry that has the characteristics of three levels of representation, namely macroscopic, submicroscopic, and symbolic. Hydrocarbon includes the structure, name, physical and chemical properties, and reactions of alkane, alkene, and alkyne compounds. At the macroscopic level, students are expected to be able to observe physical properties such as boiling point, solubility, and reactivity of hydrocarbon compounds that are clearly visible. At the submicroscopic level, students need to understand the structure of particles and bonds between atoms in hydrocarbon molecules, for example the shape of the carbon chain and bond configuration in alkenes or alkynes. Meanwhile, students' symbolic ability can be seen from their ability to write hydrocarbon molecular formulas, describe isomers, and write and balance chemical reactions such as combustion or halogenation halogenasi (Baptista et al., 2019; Ulva, Mahardika, & Nuriman, 2021).

The topic of hydrocarbons, as part of organic chemistry, is a basic material that has abstract characteristics, requiring an understanding of molecular structure, chemical reactions, and the application of chemical symbols. Many students have difficulty in linking these three representations (Langitasari, 2016; Safitri et al., 2019; Permatasari & Subali, 2020). However, research specifically analyzing the mastery and integration of these three levels of representation in hydrocarbon material is still limited. Therefore, this study was conducted to analyze students' multiple representational abilities in comprehensively understanding hydrocarbon material. The purpose of this study was to determine the level of multiple representational abilities of chemistry education students.

METHODS

The type of research used in this study is quantitative descriptive research. This research aims to describe systematically, factually, and accurately about the ability of multiple representations of students in understanding hydrocarbon. Quantitative approach is used as the main approach, with data presented in the form of numbers from written test results. This research was conducted in the even semester of the 2024/2025 academic year and took place at the Chemistry Education Study Program, Faculty of Teacher Training and Education, Tanjungpura University. The research subjects were students of class 2022 and 2023 who had taken the Organic Chemistry of Monofunctional Compounds course totaling 108 students.

The study focused on analyzing students' representation skills across three levels macroscopic, submicroscopic, and symbolic representations in solving problems related to hydrocarbon. This study used instruments in the form of written tests and documentation. Quantitative data was obtained from the results of a 9-item description test that included three levels of representation, namely macroscopic, submicroscopic, and symbolic, which were developed directly by the researcher based on the representation indicators of hydrocarbon. Before being used in data collection, the test instrument was first tested for content validity by two expert validators. The validation results showed that there was input to improve the sentences in question numbers 2, 3, 6, 7, and 8 to make them easier for students to understand.

Data collection techniques used descriptive and quantitative data analysis. In general, data analysis activities are carried out with the following steps; Several stages carried out to obtain data consist of two stages, namely the preparation stage and the implementation stage. The preparation stage consists of (1) conducting a preliminary study; (2) compiling research instruments in the form of a grid of multiple representation questions, description test questions, and scoring rubrics; (3) carrying out validation tests of research instruments by expert validators; (4) making improvements to research instruments based on validation tests by expert validators; (5) carrying out tests of questions that have been declared valid.

Next is the implementation stage. The implementation stage consists of (1) conducting written tests to students of class 2022 and 2023 of the Chemical Education Study Program, FKIP Untan who took the organic chemistry course of monofunctional compounds totaling 108 people conducted offline in the campus room; (2) correcting students' multiple representation test answers; (3) analyzing students' multirepresentation abilities.

To analyze quantitative data, the data that has been obtained is then analyzed by correcting and scoring student answers according to the scoring guidelines as follows: 1 = Less; 2 = Enough; 3 = Good; 4 = Very Good. This scoring scale refers to the descriptive assessment guidelines developed by Arikunto (2012), which are often used in educational research to categorize levels of mastery based on the scores obtained by respondents.

After giving the score, then calculate the percentage of students' multiple representation ability on each representation in Microsoft Excel. This quantitative data analysis in the form of percentages is also based on an evaluative approach commonly used in quantitative descriptive research to simplify the interpretation of the results (Sugiyono, 2019).

Next, calculate the average number of student scores on hydrocarbon questions at each level of macroscopic representation, submicroscopic representation, and symbolic representation, then identify the ability category of each representation obtained from the calculation of student scores according to the ability category scale proposed by Arikunto (2012).

Table 1. Ability Category

Score	Ability Category
81 – 100	Very good
61 - 80	Good
41 - 60	Enough
21 - 40	Less
<20	Very less

Arikunto (2012).

RESULT AND DISCUSSION

Based on the research conducted on the description test given to 57 students of the Class of 2022 and 51 students of the Class of 2023 includes 9 questions in which the 9 points cover the three levels of chemical representation. The levels of chemical representation are macroscopic, sub-microscopic, and symbolic levels. These three levels of representation refer to the framework described by Gilbert and Treagust (2009), where macroscopic representations relate to directly observable phenomena, submicroscopic ones reflect invisible structures and particles, and symbolic ones include chemical notation, formulas, and reaction equations. The percentage of multirepresentation ability of chemistry education students of FKIP Tanjungpura University on hydrocarbon based on the data obtained is described in tables 2, 3, 4 and 5.

Table 2 Average Percentage of Results of Multirepresentation Ability of Batch 2022 and Batch 2023 Students Based on Ability Category (Arikunto, 2012).

Ability Representasion	Batch 2022	Ability Category	Batch 2023	Ability Category
Macroscopik	64,86	Good	68,30	Good
Submicroscopic	69,59	Good	70,26	Good
Symbolic	67,10	Good	53,43	Enough

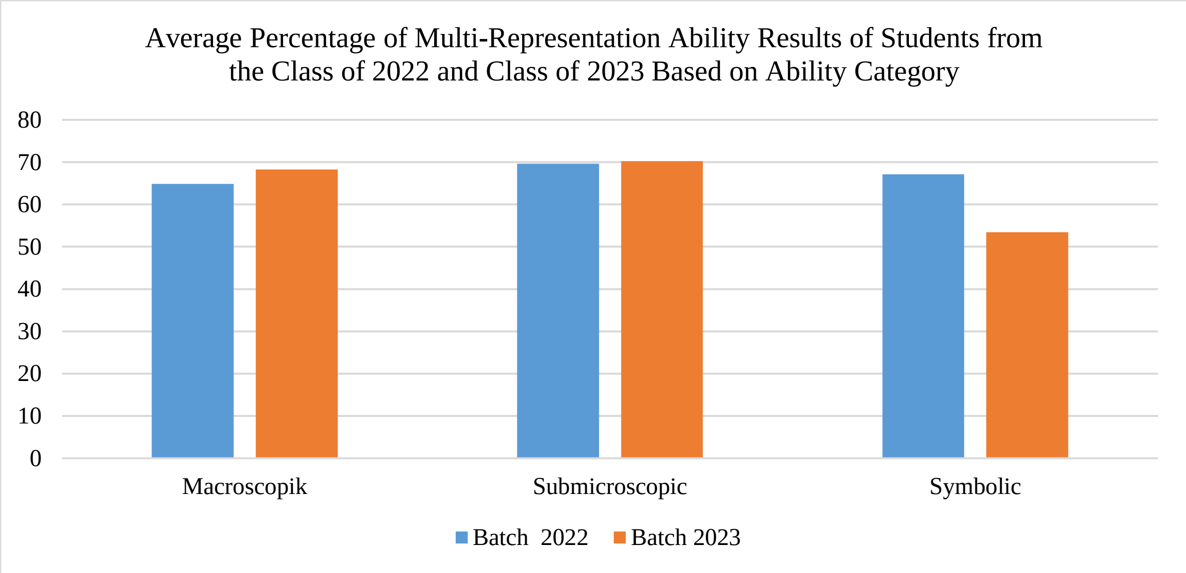

Figure 1. Average Percentage of Multi-Representation Ability Results of Students from the Class of 2022 and Class of 2023 Based on Ability Category

Table 3. Percentage of the number of students in batch 2022 and batch 2023 in Macroscopic level representation

No	Problem	Percatage (%) Understanding Batch 2022	Category	Percatage (%) Understanding Batch 2023	Category
1	S1	72,37	Good	80.88	Good
2	S2	61,84	Good	65.69	Good
3	S3	59,65	Enough	58.33	Enough
Average		**64,86**	**Good**	**68,30**	**Good**

Table 4 Percentage of the number of students in batch 2022 and batch 2023 in Sub- Microscopic level representation

No	Problem	Percatage (%) Understanding Batch 2022	Category	Percatage (%) Understanding Batch 2023	Category
4	S4	35,96	Less	32.35	Less
5	S5	93,42	Very good	97.55	Very good
6	S6	79,39	Good	80.88	Good
Average		**69,59**	**Good**	**70,26**	**Good**

Table 5 Percentage of the number of students in 2022 and 2023 in Symbolic level representation

No	Problem	Percatage (%) Understanding Batch 2022	Category	Percatage (%) Understanding Batch 2023	Category
7	S7	55,70	Enough	41.18	Enough
8	S8	53,95	Enough	35.29	Less
9	S9	91,67	Very good	83.82	Very good
Average		**67,10**	**Good**	**53,43**	**Good**

As shown in Table 3, the macroscopic representation abilities of students from the 2022 and 2023 cohorts are categorized as good, with average scores of 64.86% and 68.30%, respectively. In question 1, both cohorts demonstrated a strong understanding of the solubility concept of cycloalkanes (72.37% for the 2022 cohort and 80.88% for the 2023 cohort). However, a small number of students failed to explain why cycloalkanes are soluble in water and organic solvents.

Question 2 revealed that most students could identify the compound with the highest boiling point (61.84% for the 2022 cohort and 65.69% for the 2023 cohort), yet a few students merely named the compound without providing a scientific explanation. Question 3 had the lowest percentage (59.65% for the 2022 cohort and 58.33% for the 2023 cohort), indicating that most students' understanding was insufficient to comprehensively explain the properties of alkane compounds found in LPG. These findings align with the research by Isnaini and Ningrum (2018), which states that students' difficulties in representing organic chemistry concepts lie at the macroscopic level.

Students' difficulty in explaining the reasons behind macroscopic phenomena (solubility, boiling points, and properties of alkanes in LPG) indicates that although students are able to observe phenomena (macroscopic representation), they are not yet fully capable of connecting these observations with the underlying scientific explanations or theories at the submicroscopic or symbolic levels. Isnaini and Ningrum (2018) also found that in macroscopic representation, students had difficulty connecting conceptual understanding with chemical changes occurring in hydrocarbons, Although the results indicate that students' macroscopic abilities are quite good, they still struggle to explain the scientific reasons behind the observed phenomena. This suggests that students need more practice connecting what they see to explanations of underlying chemical concepts.

Based on Table 4, the submicroscopic representation abilities of students from the 2022 and 2023 cohorts are categorized as good, with average scores of 69.59% and 70.26%, respectively. In question 4, both cohorts showed the lowest performance (35.96% for the 2022 cohort and 32.35% for the 2023 cohort), indicating that most students struggled with selecting the main chain, numbering, and naming substituent groups. Question 5 received excellent scores (93.42% for the 2022 cohort and 97.55% for the 2023 cohort), demonstrating that most students were able to correctly draw the structure of propylene. Question 6 also yielded good results (79.39% for the 2022 cohort and 80.88% for the 2023 cohort), reflecting a strong understanding of alkane isomerism. However, a small number of students made minor errors, such as drawing only one isomer out of two possible isomers, and some made mistakes in the hydrocarbon structure, specifically in the number of hydrogen atoms, although there are still difficulties in naming and determining the main chain002E

In Table 5, the symbolic representation ability of students from the 2022 and 2023 cohorts falls into the good and sufficient categories, with average scores of 67.10% and 53.43%. Question 7 indicates that most students still had difficulty writing the chemical equation describing the reaction between 2-Bromo-2-methylpropane with magnesium in dry ether (55.70% for the 2022 cohort and 41.18% for the 2023 cohort). Question 8 was categorized as sufficient and lacking (53.95% for the 2022 cohort and 35.29% for the 2023 cohort) because most students were unable to write the elimination reaction completely and correctly for the formation of alkenes from an alkyl halide compound 1-bromobutane. This aligns with Davidowitz, Chittleborough, & Murray (2010) who stated that novice chemistry learners would experience difficulty in connecting submicroscopic and symbolic representations, especially in chemical equations.

Conversely, question 9 achieved very good results (91.67% for the 2022 cohort and 83.82% for the 2023 cohort), with most students demonstrating a strong understanding of general hydrocarbon formulas, though a small proportion of students still struggled with writing general hydrocarbon formulas due to minor errors such as formatting or atom count calculations. Overall, students understand hydrocarbon formulas quite well, but still have difficulty writing chemical reactions completely and correctly.

The results of this study indicate that hydrocarbon material requires high abstract thinking and visualization skills because many concepts cannot be directly observed. The use of three levels of representation (macroscopic, submicroscopic, and symbolic) is crucial for comprehensively understanding chemical concepts (Gilbert & Treagust, 2009). However, previous research by Langitasari (2016) and Safitri et al. (2019) also found that many students have difficulty connecting these three representations. The difficulties of the Class of 2023 students with symbolic representation, with an average category of "Fair," indicate that they are still hampered in writing and interpreting chemical reaction symbols and equations. This is important because symbolic representation is a way to describe changes in matter at the macroscopic and submicroscopic levels (Taber, 2013).

The relatively good abilities at the macroscopic and submicroscopic levels in both classes indicate that students are able to observe visible phenomena and have an initial understanding of particle models. However, this study confirms that mastery of one level of representation does not necessarily guarantee mastery of the other levels, especially if there is no strong integration between them (Treagust, Chittleborough, & Mamiala, 2003). Therefore, the Class of 2022's greater consistency in symbolic representation compared to the Class of 2023 is an important point for future learning strategies, so that students can build a more balanced and comprehensive conceptual understanding through the integration of all three levels of representation with the help of visualization.

CONCLUSION

This study shows that Chemistry Education students of the Faculty of Teacher Training and Education, Tanjungpura University, class of 2022 and 2023 have relatively good multiple representation skills, especially at the macroscopic and submicroscopic levels. However, symbolic representation remains a challenge, especially for the class of 2023. This finding suggests that symbolic skills need more attention in the chemistry learning process. The novelty of this study lies in the focus of analyzing students' abilities to integrate the three levels of macroscopic, submicroscopic, and symbolic representations comprehensively in hydrocarbon material, which has rarely been studied specifically. The implication of these results is the need for a more integrative learning approach based on multiple representations to encourage students to connect what they observe, imagine microscopically, and represent through chemical symbols, in order to build a complete conceptual understanding of hydrocarbon material. Consequently, the results of this study can be the basis for developing more effective chemistry learning strategies and teaching materials, especially to improve students' mastery of symbolic representation.

RECOMMENDATIONS

The suggestions that can be given by researchers are as follows.

1. Chemistry learning can be designed by emphasizing integration between levels of representation, especially in symbolic aspects that are abstract and require deep understanding.

2. Students can continue to develop multiple representation skills through practice problems, utilization of visual media, and reflection on the relationship between chemical concepts.

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