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# Phenomenology of Conceptual Understanding Ability, Representation, and Student Algorithm on Stoichiometry Materials

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**Abstract**

One of the basics in studying quantitative chemistry is stoichiometry. Thus, skills are needed that can support students in studying stoichiometry. The purpose of this study was to determine the level of students' conceptual understanding, representation, and algorithm skills in stoichiometric material. The subjects in this study were students of the 2019 class D Chemistry study program who had studied stoichiometry in the Basic Chemistry course I. This study was a descriptive study, had a qualitative approach, and used a phenomenological design with research techniques such as tests and interviews. The results showed that the level of students' conceptual understanding ability was 32.5% in the intuitive understanding category, 37.5% in the functional misconception category, 6.25%, in the partial understanding category, 1.25% in the correct incomplete understanding category, and 22. ,5% best understanding category. The level of student representation ability in submicroscopic phenomena was 13.53% and symbolic phenomena was 70.13%. Meanwhile, the level of students' algorithmic ability is in the unstructural category, 3.75% in the multistructural category, 43.75% in the relational category, and 0% in the extend abstract category.

Keywords: stoichiometry; conceptual understanding; representation; algorithm

**Abstrak**

Salah satu dasar dalam mempelajari kimia kuantitatif adalah stoikiometri. Dengan demikian dibutuhkan kemampuan-kemampuan yang dapat mendukung mahasiswa dalam mempelajari stoikiometri. Tujuan dari penelitian ini adalah untuk mengetahui tingkat kemampuan pemahaman konseptual, representasi, dan algoritma mahasiswa pada materi stoikiometri. Subjek dalam penelitian ini adalah mahasiswa program studi Pendidikan Kimia angkatan 2019 pada kelas D yang telah mempelajari stoikiometri pada mata kuliah Kimia Dasar I. Penelitian ini merupakan penelitian deskriptif, berpendekatan kualitatif, dan menggunakan desain fenomenologi dengan teknik penelitian berupa tes dan wawancara. Hasil penelitian menyatakan bahwa tingkat kemampuan pemahaman konseptual mahasiswa yaitu 32,5% pada kategori *intuitive understanding*, 37,5% pada kategori *functional misconception*, 6,25%, pada kategori *partial understanding*, 1,25% pada kategori *correct incomplete understanding*, dan 22,5% kategori *best understanding*. Adapun tingkat kemampuan representasi mahasiswa pada fenomena submikroskopik sebesar 13,53% dan fenomena simbolik sebesar 70,13%. Sementara itu, tingkat kemampuan algoritma mahasiswa pada kategori unistruktural, 3,75% pada kategori multistruktural, 43,75% pada kategori relasional, dan 0% kategori *extend abstract*.

Kata kunci: stoikiometri; pemahaman konseptual; representasi; algoritma

## Introduction

Stoichiometry is one of the most basic concepts studied in the field of chemistry (Chong et al., 2019; Hafsah et al., 2014; Indriyanti & Barke, 2017; Sujak et al., 2017). Stoichiometry is used as the basis for studying other quantitative chemistry, such as titration and chemical equilibrium (Evans, 1970; Hanson, 2016; Indriyanti & Barke, 2017).

One measure of success in studying chemistry can be seen from understanding the concept of stoichiometry (Hanson, 2016), because the application of stoichiometry such as the mole concept is used in laboratory practice (Chong et al., 2019). In addition, understanding the mole concept also requires algorithmic skills, because in its application the mole concept does not only use multiplication or division operations, but also uses fractions or ratios (Scott, 2012). Meanwhile, the abstract nature of stoichiometry creates difficulties in connecting macroscopic, submicroscopic, and symbolic phenomena (Sunyono et al., 2013). Based on previous research, it is stated that problem-solving skills in developing meaningful chemical knowledge can be achieved by the ability to represent at three levels of chemical phenomena (macroscopic, submicroscopic, and symbolic) (Indriyanti & Barke, 2017; Sunyono & Meristin, 2018).

Based on the curriculum of the Chemistry Education Study Program of Universitas Islam Negeri Walisongo Semarang, stoichiometry material is given to first semester students in the "Kimia Dasar I" course. The results of observations that have been made show that there are four classes in the 2019 class, with two of them holding tests on stoichiometry material. The results of the analysis of test scores show that in class D there are 24 out of 27 students who get test results below 70.

The results of studies that have been carried out by previous researchers state several reasons related to the difficulties faced in studying stoichiometry including: inadequate level of conceptual understanding, abstract stoichiometric material, and lack of ability in mathematics (Bridges, 2015; Chong et al., 2019; Hanson, 2016; Mweshi et al., 2019; Okanlawon, 2012; Santos & Arroio, 2016; Shehu, 2015; Sunyono et al., 2017). In addition, the transition period from high school to university level and differences in student backgrounds are one of the responsibilities of the university to minimize potential differences in students. (Hassel & Ridout, 2018).

Thus, it is necessary to conduct an initial study of students' conceptual understanding abilities, representations, and algorithms on stoichiometric material so that the level of student abilities is obtained which can then be used as a reference in preparing the design of teaching materials and strategies or appropriate learning models (Pamungkas & Setiani, 2017). This research involves three variables which are the factors causing the difficulty of stoichiometry material being accepted by students. Through in-depth analysis with a qualitative approach and phenomenological design, it is hoped that this research can provide detailed information related to the description of students' abilities to stoichiometric material.

## Research methods

This research uses descriptive research, phenomenological design, and a qualitative approach (Creswell, 2014; Kumar, 2011). This research was conducted from April 2020 to June 2020 at the Chemistry Education Study Program, Faculty of Science and Technology, UIN Walisongo Semarang. The data sources used in this study include primary data sources and secondary data sources. The primary data source is in the form of test and interview data, while the secondary data source is in the form of previous research report data (Kumar, 2011). In this study, the sample was determined using a purposive sampling technique (Kumar, 2011). The samples in this study were students from class D of the Chemical Education study program batch 2019.

The data in this study were obtained through several data collection techniques, which include literature review, tests, and interviews (Creswell, 2014; Kothari, 1990; Kumar, 2011; Pandey & Pandey, 2015; Walliman, 2011). on the data obtained using triangulation techniques (Creswell, 2014; Mason, 2002; Walliman, 2011), member checking techniques (Creswell, 2014; Kumar, 2011), and the inclusion of documentation as a reference (Sugiyono, 2016). The data analysis in this study includes preparing data, reading the data thoroughly and in depth, creating codes, describing codes, representing analysis findings based on descriptions using qualitative narratives, and making interpretations in qualitative research (Creswell, 2014).

The code used in this research is as contained in Table 1 for conceptual understanding ability, Table 2 for representation ability, and Table 3 for algorithmic ability.

**Table 1**
Category Table of Students' Conceptual Understanding on Stoichiometry Material (Gayeta & Caballes, 2017)

| No. | Category |
|---|---|
| 1. | Best Understanding (BU) |
| 2. | Correct Incomplete Understanding (CI) |
| 3. | Partial Understanding (PU) |
| 4. | Functional Misconceptions (FM) |
| 5. | Intuitive Understanding (IU) |

**Table 2**
Table of Students' Representation Ability Category on Stoichiometry Material (Indriyanti & Barke, 2017)

| No. | Category |
|---|---|
| 1. | Macroscopic |
| 2. | Submicroscopic |
| 3. | Symbolic |

**Table 3**
Table of Student Algorithm Ability Category on Stoichiometry Material (Herliani, 2016)

| No. | Category |
|---|---|
| 1. | Prestructural |
| 2. | Unistructural |
| 3. | Multistructural |
| 4. | Relational |
| 5. | Extend Abstract |

## Results and Discussion

### Conceptual Understanding Ability

Analysis of conceptual understanding is carried out to identify the knowledge acquired by students in high school, expand incomplete knowledge schemas, and provide solutions to misunderstandings caused by inaccurate initial knowledge (Gayeta & Caballes, 2017).

Based on Figure 1, it is known that the students' conceptual understanding ability on stoichiometric material is dominated in the FM (Functional Misconception) category. The examples of answers given by students in the FM category are as shown in Figure 2.

Based on Figure 2, it can be seen that in the concept of percent results , students assume that there is a difference between theoretical results and experimental results because there is a product that evaporates so that it can reduce the final result. These answers were then confirmed through interviews as follows.




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**Figure 1**
Percentage of Students' Conceptual Understanding on Stoichiometry Materi

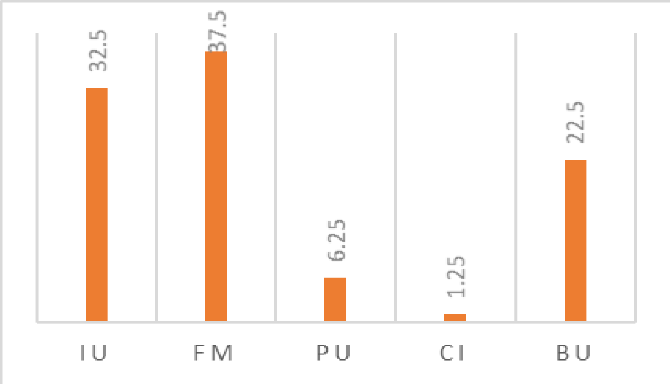
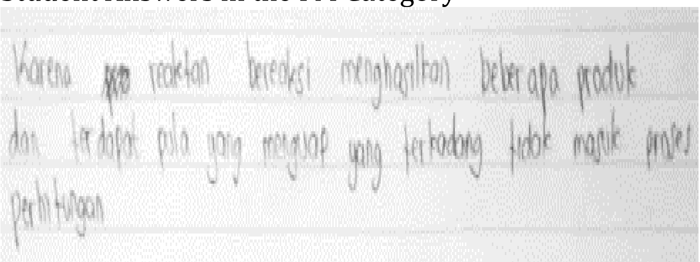



**Figure 2**
Student Answers in the FM Category




Based on Figure 2, it can be seen that in the concept of percent results , students assume that there is a difference between theoretical results and experimental results because there is a product that evaporates so that it can reduce the final result. These answers were then confirmed through interviews as follows.

Q : “In yesterday's test, you stated that the presence of a vaporized product caused a difference between the theoretical and experimental results? ”

R6 : "Yes madam”

Q : “If the product is a solid or a liquid, is there still a possibility that there will be a difference between the theoretical results and the experimental results? ”

R6: "As long as there are no impurities or errors from the practitioner, the results will be the same"

Based on the answers given by students, it is possible that the cause of this misconception is due to incomplete reasoning. In the concept of experimental results and theoretical results, students give conclusions that are too general, resulting in misconceptions (Astuti & Redjeki, 2016).

**Representation Ability**

In this study, students' ability to represent stoichiometric material is limited to submicroscopic and symbolic phenomena. This is because the research that has been done by previous researchers has shown that students' representational abilities on macroscopic phenomena are quite good compared to other phenomena (Fahriyah & Wiyarsi, 2017; Santos & Arroio, 2016; Sukmawati, 2019) . Based on Table 4, it can be seen that the representation ability of students on submicroscopic phenomena is 13.54 %. The examples of student answers on submicroscopic phenomena are shown in Figure 3.

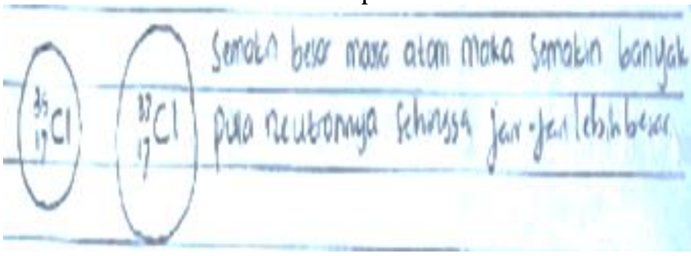
Based on Figure 3, it is known that students understand the difference in atomic mass in an isotope due to the difference in the number of neutrons. However, in their submicroscopic representation, students described ${}_{35}Cl$ and ${}_{37}Cl$ atoms with different sizes.

This causes the submicroscopic representation given by students to be inaccurate because the size of the radius of an atom is determined by the number of electrons (Chang, 2003).

**Table 4**
Representation Ability Table Student on Stoichiometry Materi

| No. | Representation Ability | % |
|---|---|---|
| 1. | Submicroscopic | 13.54 |
| 2. | Symbolic | 70.13 |

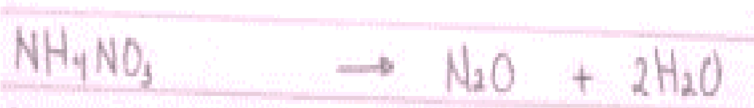
**Figure 3**
Students' Answers on the Representation of Submicroscopic Phenomena




Based on the research that has been done, there are several reasons that cause the low ability of students' representation on submicroscopic phenomena. These reasons include the fact that in chemistry learning so far, more emphasis is placed on representations of macroscopic phenomena and symbolic phenomena, so that representations of submicroscopic phenomena have been neglected (Sukmawati, 2019). In addition, student errors in understanding stoichiometry can also cause students' inaccuracy in giving expressions in submicroscopic phenomena. (Indriyanti & Barke, 2017).

Meanwhile, based on Table 4, it is known that the representation ability of students on symbolic phenomena reaches 70.13%. Based on the test results on the equivalent chemical reaction equation, many of the students did not list the phases of the compounds involved in the reaction as shown in Figure 4.

**Figure 4**
Students' Answers to the Representation of Symbolic Phenomena




The answer is then confirmed as in the following interview excerpt.

P :" In your opinion, is it important or not to write the phase symbol in a chemical reaction equation? ”

R6 : "For ordinary equations, I think it's okay not to include the phase. But for the reaction equation in question the Gibbs free energy, enthalpy, entropy must be accompanied by a phase because even though the substances are the same, if the phases are different the value will also be different.”

Based on the research that has been done, it can be seen that the representation ability of students on symbolic phenomena is better than representation on submicroscopic phenomena. This is because in its application chemistry more often uses mathematical symbols, formulas, and equations to show the relationship between macroscopic, submicroscopic, and also symbolic phenomena (Sukmawati, 2019) .

## Algorithm Ability

The algorithmic ability of Chemistry Education study program students in class D class 2019 is dominated by the relational category as shown in Figure 5 with a percentage of 43.75 %. This shows that students' algorithmic abilities are quite good, considering that in the relational category students are able to combine separate pieces of information, think flexibly, and can perform procedural operations so that students can solve problems and provide correct conclusions.

One example of student answers in the relational category is in a problem that involves determining the average atomic mass of Cl. In this problem, students can combine pieces of information in the form of atomic mass for each isotope and also the percent abundance. The information is then processed by students flexibly and calculated procedurally so that conclusions are obtained in the form of the average atomic mass of Cl exactly as shown in Figure 6.

**Figure 5**
Percentage of Student Algorithm Ability in Stoichiometry

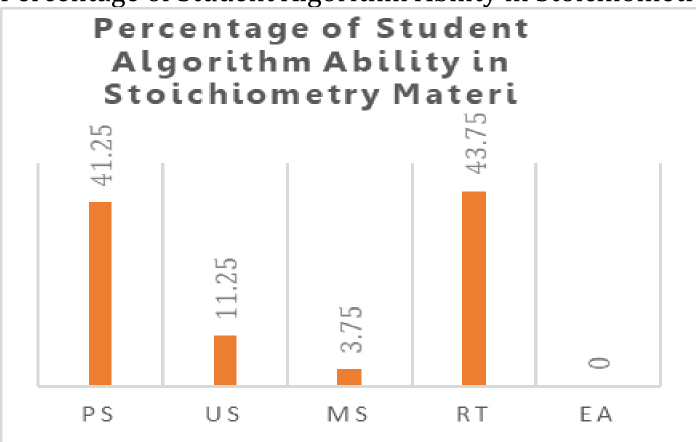
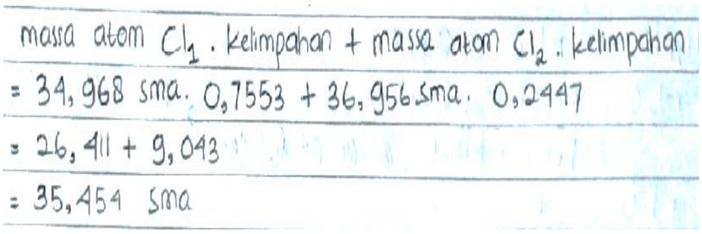
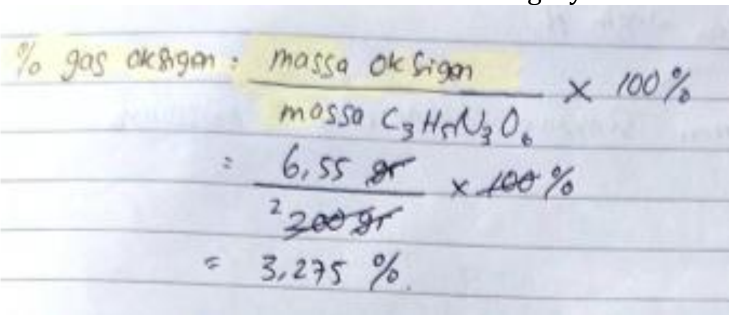



**Figure 6**
Student Answers in the Relational Category




However, based on Figure 5, it can be seen that the second highest category of students' algorithmic abilities is the prestructural category with a percentage of 41.25%. One of the questions dominated by the prestructural category is the question of determining the percentage of results. The students' answers in the prestructural category on the question of determining the percentage of results are shown in Figure 7.

**Figure 7**
Student Answers in the Prestructural Category



The answers given by students as shown in Figure 7 show that in determining the percentage of results, students only use the information available in the questions without processing it first. In Figure 7, students compare the mass of $O_2$ (product) based on the experiment to the mass of $C_3H_5N_3O_9$ (reactants). The answers given by students at the time of the test were then confirmed through interviews.

Q : "What do you think the percentage yield is?"

R3 : "So the percent result is the result of the answer multiplied by 100, madam"

Based on the results of tests and interviews given by students, it can be seen that the answers given by students indicate that students are only able to receive limited information. This makes students unable to connect the available information to solve problems (Herliani, 2016). On the ability of the algorithm, the research data obtained shows that students can perform calculation operations. However, in solving problems, students mastered problem solving procedures rather than concepts which resulted in incorrect answers.

## Conclusion

Based on the research that has been done, it can be concluded that students' conceptual understanding abilities are dominated by the category of functional misconceptions, less submicroscopic representation abilities and better symbolic representation abilities, and algorithmic abilities which are dominated by relational and prestructural categories. Recommendations for future research are that it is necessary to design strategies, models, and learning media that can support students' conceptual understanding, representation, and algorithm skills on stoichiometric material.

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