# EFFECTIVENESS OF MULTIPLE REPRESENTATION LEARNING MODEL (SIMAYANG) ON MENTAL MODEL IMPROVEMENT OF CHEMISTRY PRE-SERVICE TEACHER IN INTERMOLECULAR FORCES CONCEPT

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## ABSTRAK

Model mental ilmiah sangat penting dimiliki oleh seorang guru kimia. Namun, telah diketahui bahwa hanya 1% mahasiswa calon guru kimia angkatan 2017 Prodi Pendidikan Kimia UIN Walisongo Semarang yang mengembangkan model mental ilmiah pada konsep gaya antar molekul. Penelitian ini bertujuan untuk mengetahui efektivitas model pembelajaran SiMaYang terhadap perbaikan model mental mahasiswa calon guru kimia. Desain penelitian ini menggunakan *quasi experimental design* dengan subjek penelitian adalah mahasiswa calon guru kimia angakatan 2017. Hasil analisis menunjukan taraf *Asymp. Sig* (*2-tailed*) adalah sebesar 0.000 < 0.05. Hasil tersebut menunjukan bahwa model pembelajaran SiMaYang efektif dalam upaya perbaikan model mental mahasiswa calon guru kimia pada konsep gaya antar molekul. Hal ini diperkuat dengan jumlah mahasiswa yang memiliki model mental ilmiah di kelas eksperimen sebanyak 44% dan nilai uji N-Gain sebesar 6.0 dengan kategori sedang.

**Kata kunci** : SiMaYang, Multipel Representasi, Model Mental, Gaya Antarmolekul

## *ABSTRACT*

*Scientific mental models are fundamental to be possessed by a chemistry teacher. However, it is known that only 1% of chemistry pre-service teachers for the 2017 class of Chemistry Education Department of UIN Walisongo develop scientific mental models on the concept of intermolecular forces. This study aims to determine the effectiveness SiMaYang learning model to improve mental models of chemistry pre-service teachers. The design of this study uses a quasi-experimental design with the subject of research is a chemistry pre-service teacher for the 2017 class. Analysis shows the Asymp level. Sig (2-tailed) is 0,000 <0.05. These results indicate that the SiMaYang learning model effectively improves the mental models of chemistry pre-service teachers on the concept of the intermolecular force. This is reinforced by the number of chemistry pre-service teacher who have* *scientific mental models in the experimental class that is 44%, no initial mental model found, and the N-Gain test value is 6.0 in the medium category.*

***Keywords**: SiMaYang, Multiple Representation, Mental Model, Intermolecular Forces*

**INTRODUCTION**

The distinctive characteristic of chemistry as part of natural science is that chemistry is studied through three levels of representation (Johnstone, 1993; Gilbert and Treagust, 2009). The three levels of representation are the macroscopic level, the submicroscopic level, and the symbolic level. Thus, chemistry always involves processes that can be sensed (macroscopic) and processes that cannot be perceived (submicroscopic). All these sections are then written in a mathematical, symbolic language (Tasker and Dalton, 2006). This aspect is known as the symbolic level.

Understanding the three levels of representation in chemistry is also called mental models (Jansoon, Coll, and Somsok, 2009). Chittleborough, (2004) suggests that mental models can be defined as ideas, images, models, experiences, and other sources that develop in students' minds. The images created in students' minds are the way for them to explain a natural phenomenon that occurs.

Vosniadou and Brewer, 1992) explained three types of mental models: the scientific model, the initial model, and the synthetic model. A scientific model is a mental model that contains perception following scientific concepts. Initial models are perceptions that are not compatible with scientific knowledge, while synthetic models are mental models that contain perceptions that are partially compatible with scientific knowledge.

Fikriyah, (2018) analyzed mental models of chemistry pre-service teachers at UIN Walisongo Semarang on intermolecular forces. The study results show that 90% of the 2017 chemistry pre-service teacher developed synthetic mental models, 9% showed initial mental models, and only 1% showed scientific mental models in explaining the phenomenon of intermolecular forces.

A chemistry pre-service teacher must have a complete conceptual understanding. It is explicitly explained that one of the teacher competencies is professional competence (*UU No 14 Tahun 2005 Tentang Guru dan Dosen*, 2005). Therefore, a teacher must comprehensively master the topic in their respective fields. If a pre-service chemistry teacher has an unscientific mental model, the wrong understanding of the concept will also be carried away in the learning process they are doing. Therefore, there needs to be an effort to improve so that pre-service chemistry teachers have a scientific mental model.

The SiMaYang learning model is a chemistry learning model (Sunyono, 2012). This learning model integrates the three levels of chemical representation, namely macroscopic, sub-microscopic, and symbolic representations. When the three levels of chemical representation are integrated, the mental models built by students will be good.

Sunyono *et al.* (2013) carried out efforts to develop mental models of students. Their research shows that through the SiMaYang learning model, students' scientific mental models on stoichiometric material can be developed effectively. In addition, the research results of Yuanita and Ibrahim, (2015) show that this learning model can effectively improve student's mental models on atomic structure material compared to conventional learning models.

This research is a quantitative study (Arifin, 2014; Sugiyono, 2007) with a quasi-experimental research design using the nonequivalent control group design model (Creswell, 2009). The population in this study were all students of 2017 chemistry pre-service teachers. The sampling process was carried out by using the cluster random sampling technique.

The data collection technique in this research is to use the test technique. The type of test used is an essay test in the form of a Mental Model Diagnostic Test. The instrument used in this study is an instrument that has been developed by Fikriyah (2018) and has been declared a valid instrument based on expert validation tests and statistical item validation. In addition, the reliability of this instrument has been tested, and the instrument reliability value is 0.816, which is categorized as very good.

The process of analyzing mental models of chemistry teacher candidate students who are taught with the SiMaY learning model is carried out by looking at the tendency of the level of understanding of the descriptions given by students in answering the questions posed for each phenomenon of intermolecular forces in research instruments (Kurnaz & Eksi, 2015). The rubric for assessing student answers based on the level of understanding is shown as follows.

Table 1. Scoring Rubric Description of Intermolecular Forces

| Understanding level | Score | Criteria |
|---|---|---|
| *Sound Understanding* (SU) | 4 | All descriptions given are following scientific concepts. |
| *Partial Understanding* (PU) | 3 | Some of the descriptions given are following scientific concepts. |
| *Partial Understanding with Alternative Concertion* (PU-AC) | 2 | The description given is understandable but contains alternative concepts. |
| *Alternative Conception* (AC) | 1 | The description given is not following scientific concepts, is not logical, and is not valid. |
| *No Understanding* (NU) | 0 | Does not describe, does not finish describing, and is not relevant to the question |

The assessment of student answers is then used as a basis for determining the type of mental model being developed. There are three mental models, namely scientific mental models, synthetic mental models, and initial mental models (Vosniadou and Brewer, 1992). Classification of mental models based on the rubric as follows.

Table 2. Mental Model Assessment Rubric

| Mental Model | Content | Understanding Level of Question | | |
|---|---|---|---|---|
| | | a | b | c |
| Scientific | Perception following scientific knowledge. Description | 4<br>3 | 4<br>3 | 4<br>3 |

| | | | | |
|---|---|---|---|---|
| | answers at comprehension levels 3 (PU) and 4 (SU). | | | |
| Synthetic | Perceptions are partly appropriate or inconsistent with scientific knowledge. | All possible | | |
| Initial | Perceptions that are not following scientific knowledge. Description answers at comprehension level 0 (NU), 1 (AC), 2 (PU-AC) | 2<br>1<br>0 | 2<br>1<br>0 | 2<br>1<br>0 |

The mental models of students being analyzed are for the following concepts:

1. The concept of ion-dipole force on the phenomenon of dissolving table salt in water (Phenomenon 1).
2. The concept of hydrogen bonding in the phenomenon of dissolving vinegar in water (Phenomenon 2).
3. The concept of dispersion forces on the phenomenon of liquid CO2 injection in carbonated drinks (Phenomenon 3).
4. The concept of the dipole-dipole force on the phenomenon of the lower boiling point of acetone than the boiling point of water (Phenomenon 4).
5. The concept of the dipole force is affected by the phenomenon of dissolving CO2 in water (Phenomenon 5).

The analysis was carried out quantitatively through non-parametric statistical analysis. This is done because the number of subjects in each class in this study is less than 30 subjects. The hypothesis testing was carried out with the Mann-Whitney test model (Anwar, 2009), assisted by SPSS 16.0 application with a confidence level of 95%. In addition, the analysis of the N-Gain test was also carried out on the data from the mental model diagnostic test results with the help of the Microsoft Office Excel application.

## DISCUSSION

The analysis of understanding the multilevel representation of the answers of chemistry pre-service teachers to each question indicator shows the percentage level of student understanding as shown in Table 3 below.

Table 3. Percentage of understanding on the multilevel representation

| Understanding Level | % Understanding Level in Multilevel Representation | | |
|---|---|---|---|
| | Macro | Sub-micro | Symbol |
| SU | 29% | 22% | 95% |
| PU | 37% | 24% | - |
| PU-AC | 19% | 6% | - |
| AC | 14% | 8% | - |
| NU | 1% | 40% | 5% |

After the student's level of understanding is determined, then the student's mental model classification is carried out. For example, the average percentage of the three types of mental models developed by the chemistry pre-service teacher of class 2017 at UIN Walisongo Semarang was obtained using the SiMaYang learning model as shown in Figure 1 below.

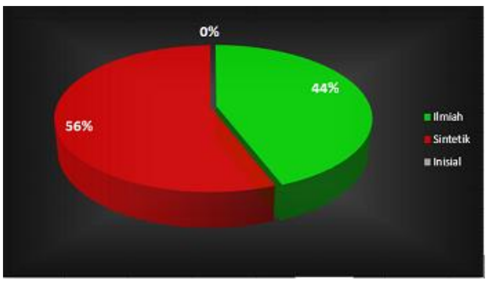


Figure 1. Developed mental model

Students who are taught using the SiMaYang learning model only develop synthetic and scientific mental models. There were no students who developed an initial mental model. The following is a detailed discussion of the mental models developed by chemistry pre-service teacher for each proposed phenomenon.

The first phenomenon is about the solubility of table salt in water. Based on the theory, dissolution of table salt is the result of ion-dipole interactions between the ions that make up table salt and water (Brady, 1990; Petrucci, 2011). The findings show that some of chemistry pre-service teacher can describe this phenomenon. On the otherhand, some of them have not been able to explain this phenomenon at the submicroscopic level. This has also been expressed by Ngurah, *et.al* (2016) that the inability of students to explain the phenomenon of the solubility of salt in water is due to the lack of ability to reason and the knowledge possessed is not applied in explaining the phenomenon at the macroscopic and submicroscopic levels.

The second phenomenon is the process of dissolving vinegar in water. Vinegar can dissolve in water because of the interaction of hydrogen bonds between the oxygen atoms in the vinegar molecule and the hydrogen atoms in the water molecules or otherwise (Effendi, 2006). Most of chemistry pre-service teacher can understand according to the scientific concept. Some of them revealed that the dissolution of vinegar in water is due to the polarity of its compounds. This is the basis that the interactions that occur between the two molecules are dipole-dipole forces. Of course this is not in accordance with scientific concepts. This finding was also confirmed by Andhini (2010) and Ngurah *et. al.* (2016) that the inability of students to explain the phenomenon of the solubility of acetic acid in water was due to a lack of knowledge on the concept of solubility and intermolecular forces submicroscopically and the inability to relate the macroscopic and submicroscopic levels.

The next phenomenon that is used as material in this research is the injection of liquid carbon dioxide in carbonated drinks. CO2 is a non-polar compound, so it does not have a permanent dipole but a momentary dipole due to electron polarization. A CO2 molecule that experiences a momentary dipole will induce another CO2 molecule. The region with a denser distribution of electrons (negative partial) will be attracted to the region of lower electron density in the other molecule (positive partial) which is induced. Likewise the opposite is true Chang (2003). Most chemistry pre-service teachers tend to only pay attention to the macroscopic level related to pressure. Meanwhile, the polarity of carbon dioxide as a result of the chemical bond between oxygen atoms and carbon atoms was not of much concern to them. This shows that there is an inability to master the molecular level of a phenomenon. Fauziah (2014) and Ngurah *et. al.* (2016) also confirmed that students did not understand that polarity was a result of bonding moments between atoms.

The fourth phenomenon is about the boiling point of acetone which is lower than that of water. Molecularly, the interactions that occur between acetone molecules are dipole-dipole interactions. Thus, the boiling point of acetone will be lower than that of water in which hydrogen bonding interactions occur between molecules (Silberberg, 2009). The findings show that some chemistry preservice teachers can explain this phenomenon well. However, there are still others who argue that the difference in boiling points of acetone and water is solely due to polarity. Ngurah *et. al.* (2016) explained that students did not fully understand the relationship between molecular polarity and the resulting intermolecular forces.

The last phenomenon is the dissolution of carbon dioxide in water. The partially positively charged H atoms ($\delta^+$) of the water molecule will induce the electrons to be scattered on the carbon dioxide molecule so that they are concentrated in the O atoms of the molecule. There is an attractive interaction between the H atom of the water molecule and the O atom which is now partially negatively charged ($\delta^-$) of the CO2 molecule. Thus there is an interaction between CO2 molecules with water (Silberberg, 2009). Most students can explain in accordance with scientific concepts. However, others still explain this phenomenon based on the level of polarity alone so that the submicroscopic level of the solubility of carbon dioxide in water has not been fully explained.

Based on the results, it is known that the student's abilities have not yet reached the scientific mental model. Students have not understood the concept of intermolecular forces, including the three levels of representation and their interconnections, so the mental model developed is incomplete (Treagust, Chittleborough, & Mamiala, 2013). The incompleteness of the concepts developed by students is shown by the results of research that synthetic mental models dominate.

The effectiveness test was carried out using the Mann-Whitney test. The results of the analysis show that Asym. Sig. (2-tailed) is $0.000 < 0.05$. This means that the average mental model of chemistry pre-service teacher in the classroom that using the SiMaYang learning model is better than the average mental model of chemistry pre-service teacher taught through the presentation method as is usually done in the Comprehensive School Chemistry course.

This result is also supported by improving the average mental model score in the experimental class, which is much better than the average mental model in the experimental class.

The results of the N-Gain test also show that the average N-Gain in the experimental class is in the medium category, while in the control class, it is in a low category. Thus, the results of the N-Gain test also strengthen the results of hypothesis testing.

This is also reinforced by the percentage of mental models of chemistry pre-service teachers at 44% for the category of mental scientific models. Although synthetic mental models' mental models are still much more significant, there are no longer any pre-service chemistry teachers with initial mental models. This means that there is a significant improvement compared to before any improvement efforts were made.

## CONCLUSION

The SiMaYang learning model effectively improves the mental model of chemistry pre-service teachers on the concept of intermolecular forces. This can be seen from the results of the effectiveness test where the Asym value. Sig. (2-tailed) based on the right side test is 0.000 < 0.05. These results are corroborated by an average N-Gain of 0.6 (medium category). In addition, it is also reinforced by the percentage of students who developed a scientific mental model of 44%, and another 56% developed a synthetic mental model, and there were no students who developed an initial mental model.

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