Achievement profile of high school students on chemical dynamics material at three levels of representation

A Rakhmawan¹*, H Firman², S Redjeki³ and S Mulyani²

¹Science education major, Postgraduate school, Universitas Pendidikan Indonesia, Dr. Setiabudi Street, No 229, Bandung, 40154, Indonesia
²Chemistry education department, Universitas Pendidikan Indonesia, Dr. Setiabudi Street, No 229, Bandung, 40154, Indonesia
³Biology education department, Universitas Pendidikan Indonesia, Dr. Setiabudi Street, No 229, Bandung, 40154, Indonesia

*adityarakhmawan@gmail.com

Abstract. This study aims to explore information about the achievement profile of high school students on chemical dynamics material at three levels representation. This research uses non experimental design in the form of survey. Sample of the survey was 219 students of 11th grade high school students in Ketapang, West Borneo. Cluster random sampling was used as a sampling method. The data collection of survey use a multiple choice tests that contains chemical dynamics material that includes chemical kinetic concepts and chemical equilibrium concepts. Each item of the tests contains three levels representation such as macroscopic levels, symbolic levels, and submicroscopic levels. Based on the findings, it shows that high school students in Ketapang have high mean score of symbolic representation by 55.1%, and sequentially 49.8% in macroscopic level, and 40.8% in submicroscopic level. The results based One Way ANOVA tests conclude that the mean score of each representation level was significantly different.

1. Introduction

The success of the application of learning can be seen from the grade of student learning outcomes. From the assessment of this learning outcomes a teacher or stake holder will know what to do next. High student learning outcomes, roughly indicate learning objectives are achieved. Learning objectives are a reflection of learning indicators, in other words, good achievement of learning outcomes becomes a rough consideration of national goals achievement through standards competencies (Standar Kompetensi) and basic competencies (Kompetensi Dasar). Thus, good grade of learning outcomes can be a measure of success achievement of learning indicators.

In this research, chemistry used as one of the essential subjects in high school. Based on the regulations of Permendiknas No 22 year 2006 about content standards which states that the subjects of chemistry in high school study about substances that include composition, structure and properties, changes, dynamics, and energetics. Based on this definition there are three major materials in chemistry that essential to be study, namely structure and composition, dynamics and energetics. Energetics discusses the energy involved in a chemical reaction. While dynamics discusses about the changes or movement that occurs in the chemical reaction itself.
The material of chemical dynamics is one of the branches of knowledge of chemical physics which examines phenomena related to time, in chemistry it includes reaction mechanisms, and reaction rates. Therefore, this study raised two concepts that are part of the chemical dynamics material, namely the rate of chemical reactions, and chemical equilibrium. This material of chemical dynamics is considered to be one of the most difficult materials. In addition, this chemical dynamics material is one of the fundamental materials, the one that builds chemistry concepts. Thus, if students are capable of this material, then other material should not be too difficult [1].

Chemistry is one of abstract concepts, therefore chemistry and its phenomenon are generally described in terms of three levels of representation, such as macroscopic level, submicroscopic level, and symbolic level [2]. These three levels are very strongly connected as a foundation of chemical understanding, even Gilbert and Treagust say it is a triplet relationship [3]. So one thing that measure student's level of understanding in chemistry is achievement in these three levels of representation.

This study aims to examine about the achievement of high school students in Ketapang, West Borneo, on chemical dynamics material measured through three levels of representations, namely macroscopic level, submicroscopic level, and symbolic level.

2. Method
This research uses quantitative approach with non-experimental research design that is by survey research method [4]. Data collection in this study was conducted without treatment of the subject of research, so that the data obtained is the actual situation in the field.

The data were collected using instrument of chemistry learning achievement test containing three levels of representation. The instrument is a closed ended responses instrument in the form of multiple choices. The instrument is divided into three types of items, each items measure each level of representations, 8 items measure the macroscopic level, 9 items measure the submicroscopic level, and 9 items last items measure the symbolic.

After the instrument is made, the instrument is then validated using CVR (Content Validity Ratio) method from Lawshe [5]. The CVR method in this research does not use Schipper’s critical value tables as in Lawshe, but it uses Wilson's critical value tables [6]. This Lawshe’s method involves a panel of Subject Matter Experts (SME) consisting of 5 experts who are also lecturers, which is 1 expert in basic chemistry, 1 expert in chemical physics, 2 experts in multiple representation in chemistry, and 1 expert in evaluation in chemistry.

Once validated by the experts, the instrument was then having limited trial process in one of the high schools state in Ketapang, West Borneo. A total of 72 students were involved in this limited trial process. Through this limited trial obtained data about the value of validity and reliability of instruments.

After the limited trial, then proceed with the actual research. The subjects of this study take the entire population of the senior high school state students in the District of Ketapang, West Borneo. Sampling was done by cluster random sampling method. Four schools were taken as clusters, after that in every clusters sample taken by random. A total of 219 students were involved in this research from 4 selected schools.

3. Results and discussion
Based on the results of the data collection, some finding were found that there is a difference between the students’ ability among these three levels of representation in chemical dynamics. It can be shown as in figure 1.

Based on figure 1, shows the difference between three levels of student representation on the chemical dynamics material. The majority of students have higher ability on the symbolic representation levels than macroscopic and submicroscopic representation levels. This data shows that students are more capable in the level of symbolic representation.
These three values are then tested for significance using One Way ANOVA test on SPSS 17.0. The three groups used in one-way ANOVA test are macroscopic, submicroscopic, and symbolic variables. The result of significance test using one way ANOVA is shown as in table 1.

Table 1. Significance level of each group of multiple level representations

|                  | Sum of Squares | df | Mean Square | F      | Sig.  |
|------------------|----------------|----|-------------|--------|-------|
| Between Groups   | 217.449        | 2  | 108.725     | 35.089 | 0.000 |
| Within Groups    | 1905.581       | 615| 3.099       |        |       |
| Total            | 2123.031       |    |             |        |       |

Table 1 shows that the p-value between groups of three levels representation is 0.000. If the p-value between groups less than 0.05, it indicates that 3 mean scores differences among the three groups are significantly different. In other words, we can say that the highest mean score of symbolic level is significantly better than the mean scores of macroscopic level and submicroscopic level. Similarly with the mean score of macroscopic level, it is significantly better than the mean score of submicroscopic level. Furthermore, the t-test results using each pair of groups is also showed that the symbolic level is significantly better than macroscopic level and submicroscopic level. Then the macroscopic level is significantly better than the submicroscopic level.

This shows that students are more familiar with symbols than with other representations. Teachers in its teaching process provide more problems and understanding in the realm of the symbolic representation level rather than the macroscopic and submicroscopic level of representation. Such as functions, formulas, equations, chemical reactions, numbers, and other chemical symbols.

This illustrates that the learning given in the school generally aims to solve the problems associated with the symbolic level of representation. As we know the symbolic level only aims to explain what happens at the submicroscopic level that affects the macroscopic level. Thus, this symbolic level only serves as an intermediate bridge connecting between submicroscopic and macroscopic level of representation [7].

The other results of the study which showed differences in students’ ability in two dynamics concepts, namely chemical kinetics and chemical equilibrium are shown in figure 2.
Based on figure 2, it can be seen that students’ ability in chemical kinetics concept is higher than students’ ability in chemical equilibrium concept. Students feel that the chemical equilibrium concept is more difficult than the chemical kinetics concept.

Through this research, we can also be seen the differences in the students’ ability at three levels of representation on the chemical kinetics concept itself as shown by figure 3.

Based on figure 3, it can be seen that students’ achievement on chemical kinetic concept at three levels of representation is almost equal, except for the achievement of representation at macroscopic level. If we relate to figure 2, that the chemical kinetics concept is the concept that most students can afford compared with the other concept in part of chemical dynamics material.

The results of this research, we can also seen the differences in students’ achievement between three levels of representations in the chemical equilibrium concept as shown in figure 4.

Based on figure 4, it shows the difference of students’ achievement at three levels of representation on the chemical equilibrium concept. Through this data, it can be seen that in the chemical equilibrium concept, students are most capable at the symbolic representation level compared with macroscopic level of representation and submicroscopic level of representation. Furthermore, it is known that students have difficulty at the submicroscopic level on the this material compared with macroscopic level and symbolic level of representation.

If we compare with figure 2, where the lowest achievement of student learning outcomes is in the chemical equilibrium concept. We can see that it does have a correlation where the lower students’ achievement in a subject area, will result their achievement in one level of representation become significantly difference among the three levels of representation as can be seen in figure 4. On the contrary, from figure 2 we can also conclude that the higher students’ achievement in one subject area (as for this case is chemical kinetics concept), it will make their achievement in each level of representation in that area will not significantly difference among the three level of representations as
we can see in figure 3. It’s also said by the other research that if student can’t able to connect the three level representations, it won’t make student understand chemistry concepts thoroughly and deeply [8,9].

Figure 4. Average student achievement in chemical equilibrium concept at three levels of representation.

Low achievement at submicroscopic level is due to students experiencing confusion with the properties of particles on a molecular scale [3]. In addition students have difficulty in visualizing the existence and processes occurring in the molecular realm, lack of imagination become the main reason why students have difficulties to observe the unobservable world of submicroscopic level [10]. The low achievement of the students’ learning outcome will also have an impact on the low cognitive ability of the students, one of them will have an impact in the effort to visualize submicroscopic phenomenon that occur on the molecular scale. In a more specific concept, it is seen that students have more difficulty in visualizing phenomenon problems of the equilibrium process than the phenomenon of reaction rate. In this case, learning method plays an important role to be able to integrate between the three levels of representation and it expected to be able to overcome the problems of students’ learning difficulties in chemistry [11].

4. Conclusion
High school state students in Ketapang District have high achievement at symbolic level of representations and low achievement at submicroscopic level of representations. Significance test using one way ANOVA also said that indeed that the three mean score of each levels of representations is significantly different. In other words that students in school at Ketapang District are better able to work on issues with symbolic levels of representation better than macroscopic and submicroscopic level of representation.

This can be a reflection for teachers and stakeholders of education, that the current learning process is in fact more emphasis for students to be able to solve chemistry problems at the symbolic level of representation. Chemistry learning requires a balance between three levels of representation. First, context-based learning to improve students’ representational skills at the macroscopic level. This can be done such as by experimental learning, laboratory practice, and others. Second, learning that emphasizes the imagination of students at submicroscopic level, one of the learning method that can be done such as learning by using model or multimedia.

References
[1] Nakhleh M B 1992 Why some students don’t learn chemistry: Chemical misconceptions J. Chem. Educ. 69 191–6
[2] Talanquer V 2011 Macro, submicro, and symbolic: The many faces of the chemistry “triplet” Int. J. Sci. Educ. 33 179–95
[3] Gilbert J K and Treagust D 2009 Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education Models and modeling in science education: Multiple representations in chemical education ed J K Gilbert and D F Treagust (Netherlands: Springer Science) pp 1–8
[4] Creswell J W 2009 Research design: Qualitative, quantitative, and mixed methods approaches
(Unites States of America: SAGE Publications, Inc.)

[5] Lawshe C 1975 A quantitative approach to content Pers. Psychol. 28 563–75

[6] Wilson F R, Pan W and Schumsky D A 2012 Recalculation of the critical values for Lawshe’s content validity ratio Meas. Eval. Couns. Dev. 45 197–210

[7] Taber K S 2009 Learning at the symbolic level Models and modeling in science education: Multiple representations in chemical education ed J K Gilbert and D F Treagust (Netherlands: Springer Science) pp 75–105

[8] Nahadi N, Firman H and Kurniadi H 2018 Development and validation of chemistry virtual test based multiple representations J. Educ. Learn. 12 44–51

[9] Nilawati P A, Subandi and Utomo Y 2016 Keefektifan pembelajaran interkoneksi multipel representasi dalam mengurangi kesalahan konsep siswa pada materi stoikiometri J. Pendidik. Teor. Penelit. dan Pengemb. 1 2076–82

[10] Bucat B and Mocerino M 2009 Learning at the sub-micro level: Structural representations Models and modeling in science education: Multiple representations in chemical education ed J K Gilbert and D F Treagust (Netherlands: Springer Science) pp 11–29

[11] Ristiyani E and Bahriah E S 2016 Analisis kesulitan belajar kimia siswa di SMAN X kota Tangerang Selatan J. Penelit. dan Pembelajaran IPA 2 18–29